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REPORT OF THE COMMITTEE ON DYNAMO-ELECTRIC MACHINES.

The Board of Managers of the Franklin Institute having empowered its Committee on Instruction to purchase a Dynamo-Electric Machine, it was deemed advisable to examine into the merits of, and to test, the various machines offered for sale. This was undertaken partly as a guide in making a selection for purchase, and also to obtain reliable data regarding the adaptability of such machines to the production of Light.

In view of the scientific importance of the work, the Committee on Instruction, which consists of five members of the Board of Managers, availed themselves of the services of four other members of the same, who, by request, assisted in the investigation, and now join in this report.

The work was divided among Sub-Committees as follows:

On Photometric Measurements, Messrs. Briggs, Profs. Rogers and Chase. On Electric Measurements, Profs. Houston, Thomson, and Mr. Rand. (Mr. Rand's business engagements prevented his taking active part in the work of this sub-committee.) On Dynamical Measurements, Messrs. Jones, Sartain and Knight.

Previous to the commencement of the labors of the Committee, an invitation was extended to makers of dynamo-electric machines, with a request that they should furnish machines for competitive trial. This invitation was also given in the columns of the JOURNAL of the Institute, and received general publication in the newspapers and scientific periodicals. Especial requests were addressed to M. Breguet, of Paris, France, maker of the "Gramme" machine; to Messrs. Siemens Bros., of London, Eng., makers of the "Siemens" machine; to Messrs. Condit, Hanson & Van Winkle, of Newark, N. J., makers of the "Weston" machine; to the Telegraph Supply Co., of Cleveland, Ohio, makers of the "Brush" machine; and to Messrs. Wallace & Sons, of Ansonia, Conn., makers of the "Wallace-Farmer" machine.

The only machines supplied directly from the makers were two each of the Brush and Wallace-Farmer types, but the Committee were gratified in obtaining, through the courtesy of Prof. H. W. Wiley, of Purdue University, Lafayette, Ind., a "Gramme" machine. This Gramme machine formed a part of the exhibit of M. Breguet at the Centennial exhibition, and, for this and other reasons, is believed to be a good example of its class.

The apparatus employed by the sub-committee on electrical measurements, in their determinations, were kindly loaned, for the purpose, by the Committee on the Central High School of Philadelphia, and are from the large and valuable cabinet of philosophical apparatus of that institution.

The apparatus used to measure the power required to drive the electric machine, was a Brown Dynamometer, loaned by the Fales & Jenks Manufacturing Co., of Providence, R. I.

Mr. J. W. Sutton, of N. Y., also loaned us a spring dynamometer, which is a very compact instrument, and possesses peculiar advantages for use in many locations. The circumstances, however, under which our tests were made, rendered this less available, and it was, therefore, not used.

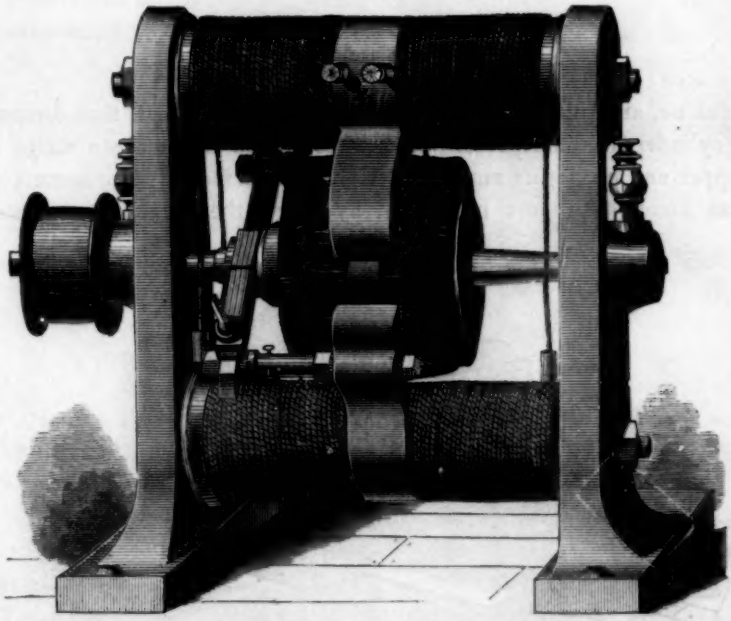
The source of power for the experiments was an upright steam-engine belonging to the Institute. It has 6″ bore of cylinder, and 8″ stroke, heavy fly-wheel 30″ diameter, and governor so adjusted as to give speeds from 100 to 250 revolutions per minute.

In measuring the power used, indicator diagrams were taken from the engine, as a check on the dynamometer readings, although the

latter were relied upon in making our calculations, except in the case of the large Wallace machine. This machine requiring more power than could be supplied by the Institute's engine, or safely transmitted by the dynamometer, it was taken to the works of the I. P. Morris Co., and driven by an engine of 9″ bore and 18″ stroke, and the amount of "power consumed" determined from the indicator diagrams. This determination was sufficient to demonstrate the fact that this machine possesses no economical advantages over the smaller one of the same make, but the "power consumed" is omitted from the table of results, as comparisons based on the different methods would be obviously unsatisfactory.

The following is a description of the machines submitted to examination. Their dimensions are given in Table I:

Fig. 1.



The Gramme machine, Fig. 1, consists of two cylindrical electro-magnets, with their combined poles extended by pieces of such shape as nearly to envelop the armature which rotates between them, Figs. 2 and 3. The armature is composed of a ring of soft iron, with insulated copper wire wound over its entire surface. This wire is divided into sixty coils connected successively at their ends, and the loops thus formed between each pair of coils are connected to the

copper strips of the commutator. Fig. 2 represents the mode of winding this wire on the ring, only a few turns, however, being shown.

The commutator consists of copper strips equal in number to the armature coils, placed radially edgewise around the shaft of the

Fig. 2.

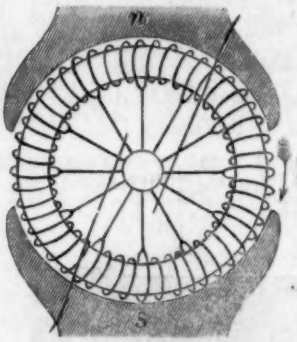
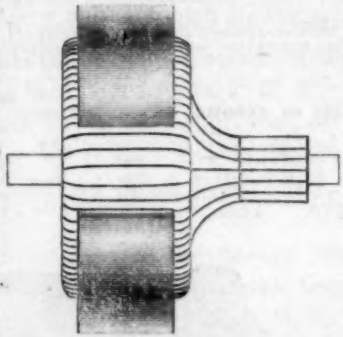
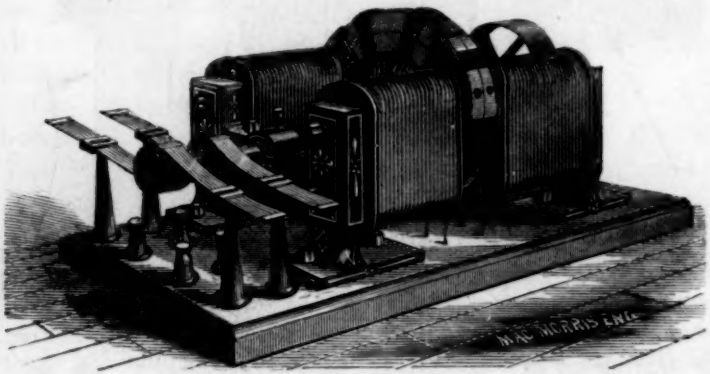


Fig. 3.



machine, and insulated from each other and the shaft, thus forming a cylinder, the surface of which is composed of alternate strips of copper and insulating material. Upon the surface of the commutator rest bundles of soft iron wire, by which the currents generated

Fig. 4.



in the armature coils are conducted to the external circuit. As the armature is rotated between the poles of the field magnets, currents of electricity are generated.

These machines are also constructed with two commutators, each connected respectively to alternate armature coils, in which case the

external circuit can be divided; but it is usual to pass both currents through the field coils, and then join them in the external circuit. This machine runs smoothly and very quietly, with few or no sparks at the commutator, and very little heating, the temperature of the armature being about 98° Fahr. after running nearly five hours.

The Brush machine, Fig. 4, has, for its magnetic field, two horse-shoe electro-magnets, with their like poles facing each other, at a suitable distance apart, the circular armature rotating between them.

In this machine the currents are generated in coils of copper wire, wound upon an iron ring, constituting the armature. This ring is not entirely covered by the coils, as in the Gramme armature, but the alternate uncovered spaces between the coils are almost completely filled by iron extensions from the ring, thus exposing large surfaces of the armature ring for the dissipation of heat, due to its constantly changing magnetism, as in the Pacinotti machine.

Fig. 5.

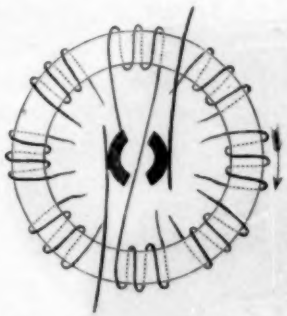
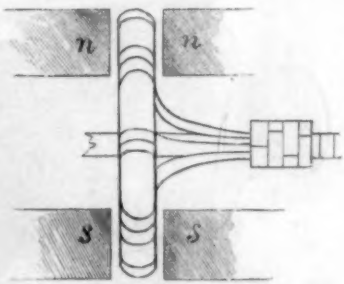


Fig. 6.



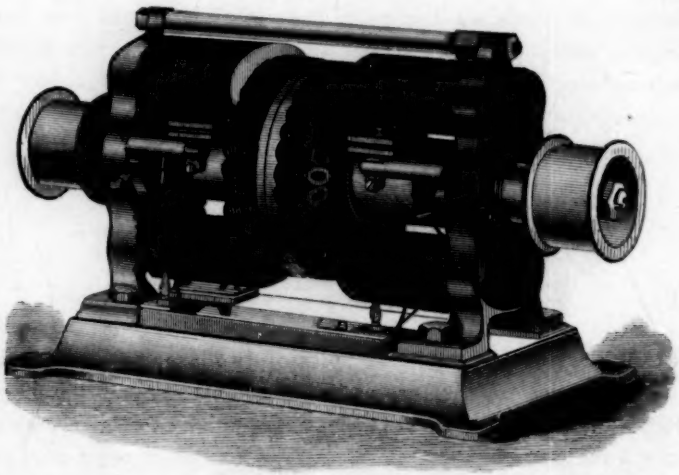
The ring revolves between the poles of two large field magnets, the two positive poles of which are at the same extremity of the diameter of the armature, and the two negative poles at the opposite extremity, each pair constituting practically extended poles of opposite character.

The coils on the armature ring are eight in number, opposite ones being connected end to end, and the terminals carried out to the commutator. Figs. 5 and 6 show this arrangement, only one pair of coils, however, being shown in Fig. 5 as connected. In order to place the commutator in a convenient position, the terminal wires are carried through the centre of the shaft, to a point outside the bearings.

The commutators are so arranged, that, at any instant, three pairs of coils are interposed in the circuit of the machine, working, as it were, in multiple arc, the remaining pair being cut out at the neutral point; while in the Gramme machine, the numerous armature coils being connected end to end throughout, and connections being made to the metal strips composing the commutator, two sets of coils in multiple arc are at one time interposed in the circuit, each set constituting one-half of the coils on the armature.

The commutator consists of segments of brass, secured to a ring of non-conducting material, carried on the shaft. These segments are divided into two thicknesses, the inner being permanently secured to the non-conducting material, and the outer ones, which take all the wear, are fastened to the inner in such a manner that they can be easily removed when required.

Fig. 7.



The commutator brushes, which are composed of strips of hard brass, joined together at their outer ends, are inexpensive and easily renewed. The high speed at which these machines are run, together with the form of the armature, cause the rotation of the latter to be considerably resisted by the air, and producing a humming sound, but otherwise they run smoothly; the heating of the armature being inconsiderable, not exceeding 120° Fahr. after four and three-quarter

hours' run. They are simple in construction, all the working parts being easily accessible, and the cost of maintenance low.

Fig. 4 represents the smaller Brush machine, which is identical in mechanical design with the larger, except that in the former there are two commutators, each of which is connected with alternate armature coils.

By this arrangement connections can be so made as to produce electric currents of high or low electromotive force (55 to 120 volts, as will hereafter be shown), or the conductor can be divided into two circuits, each of which can be utilized for producing its own light, or for performing other work.

In the Wallace-Farmer machine, Fig. 7, the magnetic field is also produced by two horseshoe electro-magnets, but with poles of opposite character facing each other. Between the arms of the magnets, and passing through the uprights supporting them, is the shaft, carrying at its centre the rotating armature.

Fig. 8.

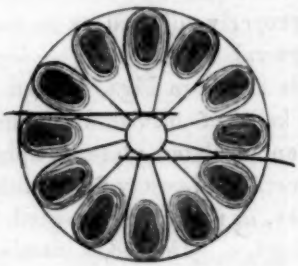
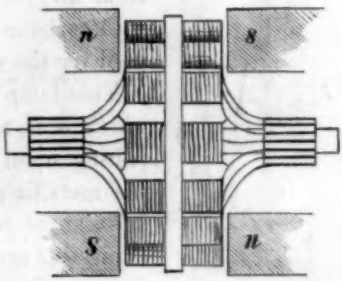


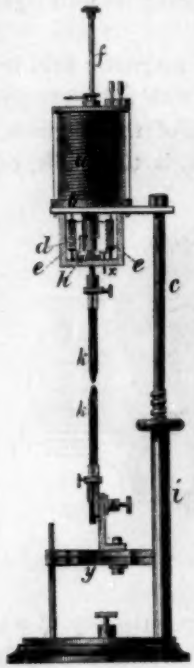
Fig. 9.



This consists of a disc of cast iron, near the periphery of which, and at right angles to either face, are iron cores, wound with insulated wire, thus constituting a double series of coils. These armature coils Figs. 8 and 9, being connected end to end, the loops so formed are connected in the same manner, and to a commutator of the same construction, as that of the Gramme. As the armature rotates, the cores pass between the opposed north and south poles of the field magnets, and the current generated depends on the change of polarity of the cores. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical

connections are so made, that the currents generated in the two series of armature coils pass through the field-magnet coils, and are joined in one external circuit. This form of armature also presents considerable uncovered surface of iron to the cooling effect of the air, but its external form, in its fan-like action on the air, like that of the Brush, presents considerable resistance to rotation. In the Wallace-Farmer machine there was considerable heating of the armature, the temperature being sufficiently high to melt sealing-wax.

Fig. 10.



The Brush and Wallace-Farmer machines were accompanied by lamps, or carbon holders, which were thought by their makers to present advantages, if not for all machines, at least to be especially adapted to the requirements of their own; the usual "Serrin" lamp, which is made by M. Breguet for the Gramme machine, did not accompany the latter. The result of experiment, however, quickly established the suitability of the Brush lamp as the source of light from all the machines, and the same lamp, with carbons properly adjusted as to size, was used for the several trials.

This lamp is shown in Figs. 10 and 11, in which *a* is a helix of insulated copper wire, resting upon an insulated plate, *b*, upheld by the metallic post, *c*. Loosely fitted within the helix is the core, *d*, partially supported by the adjustable springs, *e*. The rod, *f*, passes freely through the centre of the core, *d*, and has at its lower end a clamp for holding the carbon pencil. A washer, *h*, of brass, surrounds the rod, *f*, just below the core, *d*, and has one edge resting on the lifting finger attached to the latter, while the other edge is overhung by the head of an adjustable screw stop, *x*.

The metal post, *c*, is supported and guided by a tubular post, *i*, secured to a suitable base plate. Attached to the lower end of the post, *c*, and passing out through a slot in *i*, is the arm, *y*, supporting an insulated holder for the lower carbon.

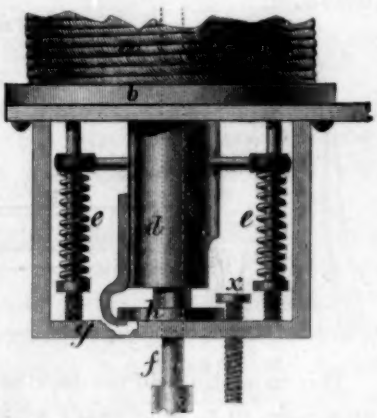
If now one conducting wire, from the machine, be connected to the base plate, and the other to the lower carbon holder, the current

of electricity will pass up through the posts, *i* and *c*, through the helix, *a*, rod, *f*, and the carbons, *k k*, thus completing the circuit.

The axial magnetism produced in the helix will draw up the core, *d*, and it, by means of the lifting finger, will raise one edge of the washer, *h*, which, by its angular impingement against the rod, *f*, clamps and lifts it to a distance controlled by the adjustable stop, *x*, but separating the carbon points far enough to produce the light.

As the carbons burn away, the increased length of the electric arc increases its resistance and weakens the magnetism of the helix, and, therefore, the coil, rod and carbon move downward by the force of gravity, until, by the shortening of the arc, the magnetism of the helix is strengthened and the downward movement arrested. When, however, the downward movement is sufficient to bring the clutch-washer, *h*, to the support, *l*, it will be released from the clamping effect of the lifting finger, and the rod, *f*, will slip through until arrested by the upward movement of the core, due to the increased magnetism of the helix.

Fig. 11.

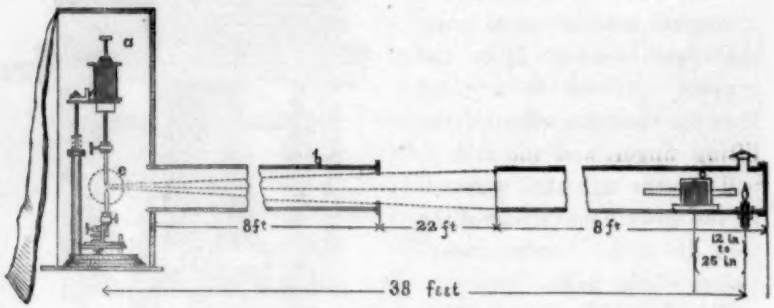


The normal position of the clamp-washer is with the edge under the adjustable stop, just touching the support, *l*, the office of the core being to regulate the slipping of the rod through it. If, however, the rod, from any cause, falls too far, it will instantly and automatically be raised again, as at first, and the carbon points thus continued at the proper distance from each other.

In the lamp used in these experiments, the helix was composed of two separate insulated wires wound together, so that, by means of suitable pin contacts, shown at the top of Fig. 10, they could be connected either in couples or end to end, thus varying the intensity of the magnetism of the helix. This, in connection with varying the weight to be lifted by the magnetism of the helix, either by loading the core or increasing the upward thrust of the springs, enabled us to adjust the lamp to suit the varying qualities of the currents dealt with.

In order to make the measurements as accurate as possible, it was found necessary so to arrange the apparatus that no reflected or diffused light should fall on the photometer, and thus introduce an element of error. The arrangement of the apparatus to accomplish this is shown in Fig. 12. The electric lamp was enclosed in a box, open at the back for convenience of access, but closed with a non-reflecting and opaque screen during the experiments. Projecting from a hole in the front of the box was a wooden tube, *b*, 6″ square inside and 8′ long, with its inner surface blackened to prevent reflection, thus allowing only a small beam of direct light to leave the box. This beam of light passed into a similar wooden tube, *c*, placed at a proper distance from the first, and holding in its farther end the standard candle, *d*.

FIG. 12.



This tube also held the dark box of a Bunsen photometer, mounted on a slide, so as to be easily adjusted at the proper distance between the two sources of light. A slit in the side of the tube enabled the observer to see the diaphragm. The outer end of the second tube was also covered with a non-reflecting hood, and the room was, of course, darkened when photometric measurements were taken. The rigid exclusion of all reflected or diffused light is believed to be the only trustworthy method of obtaining true results, and will, no doubt, account in a large measure for the lower candle-power obtained by these experiments than that obtained by many previous experimenters.

The difficulties encountered in the measurement of the light arising from the difference in color, were at first thought to be considerable, but further practice and experience enabled the observer to overcome them to such an extent that the error arising from this cause is inconsiderable, being greatly less than that due to the fluctuations of the electric arc.

The advantage to be derived from using a larger source of light than the standard candle, in measuring the electric light, was considered. A gas-flame, giving 20 candles' light, and the oxy-hydrogen light, so adjusted as to give 70 to 136 candles, were carefully measured and used as a comparison. Both of these were found unsatisfactory, and the measurements relied on for our calculations were made entirely with a standard candle, carefully corrected for any variation of consumption from 120 grains per hour.

Were much higher intensities of light to be measured, it would be well to use, as a means of comparison, a large gas-burner or a multiple-wick lamp, such as are employed in lighthouse service, its power being constantly checked by measurements with the standard candle and separate photometer; but, with the volume of light dealt with in these experiments, the candle was sufficiently large, and its direct use greatly reduced the chance of error.

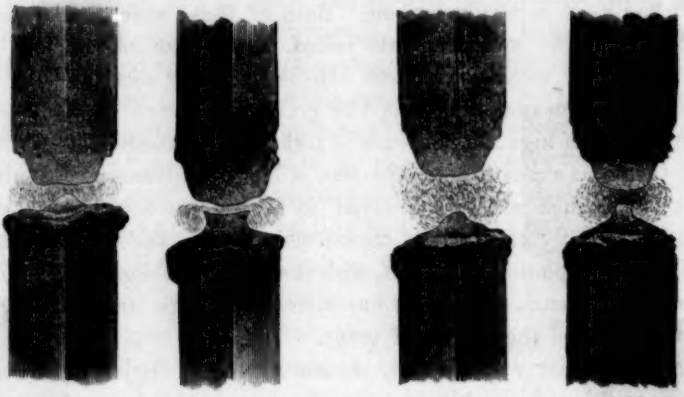
In the earlier experiments, measurements of light, current and power were made simultaneously, thus establishing standard references by which after-experiments upon the different points were connected.

In determining the amount of light produced by each machine, it was run continuously for from four to five hours, and observations made at intervals, care being taken to maintain the speed and other conditions normal. One of the most important conditions necessary to insure correct results, was the relative position of the carbon points. Great care was taken that the axes of the two sticks or pencils of carbon were in the same line, so that the light produced should be projected equally in all directions. Were the axes of the carbon pencils not in the same line, a much greater quantity of light would be projected in one direction, and the result of calculation of the light produced, based on the inverse square of the distance from the photometer, would be too great or too small, accordingly as this adjustment was in the one on the other direction.

To facilitate observations during the experiments, there was attached, at *e*, to the side of the box *a* holding the electric lamp, a focussing lens, with its axis at right angles to the beam of light, to the photometer, and an image projected upon a screen enabling the observer to see the condition and position of the carbon points without fatiguing the eye. Photographs were also taken, from time to time, at the moment of making the photometric observations—thus securing a permanent record of the condition of the carbon points.

Another difficulty in determining the exact photometric value of the electric light, is the fluctuation, or rather the moving from side to side, of the electric arc, and great care was taken so to adjust the

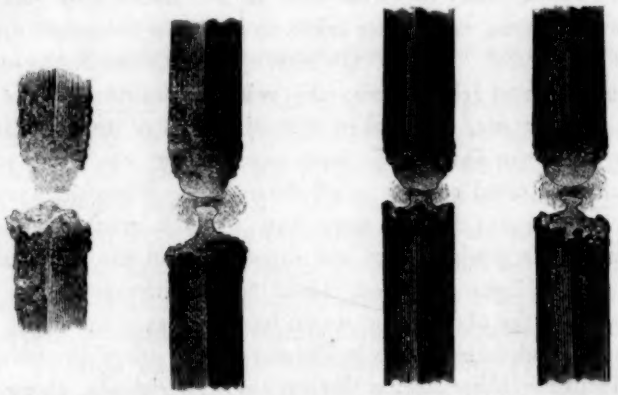
Fig. 13. Fig. 14. Fig 15. Fig. 16.



From Large Brush Machine. From Small Brush Machine.

conditions, that the arc or flame should be steady, and equally distributed about the ends of the carbon pencils.

Fig. 17.[1] Fig. 18. Fig. 19. Fig. 20.



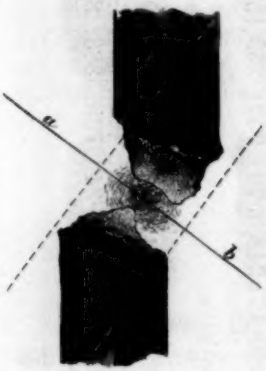
From Gramme Machine. From Small Wallace Machine.

Figs. 13 to 20 are full size, exact reproductions of the photographs taken, and fairly represent the average condition of the carbon when observations were made.

[1] The voltaic arc should have been shown in Fig. 17, as in Fig. 19. All the carbons used were coated with copper.

It was found that although there was a slow consumption of the negative carbon, there was, at the same time, a constant "stalagmitic" growth of particles carried from the positive carbon by the action of the electric current. These stalagmites assumed different forms, as shown in the cuts, but no particular form seemed to be produced by the current from the different machines, except that the deposits on the negative carbon would become greater with increased current. These deposits would build up gradually until they had assumed the forms shown in Figs. 18 and 20; then growing narrower near the base, until, by a weakening of the current by this and the consumption of the upper carbon, the lamp would readjust itself, and the piece would drop off. The effect of these growths on the intensity of the light was scarcely appreciable, except for a few seconds before and after the readjustment of the lamp.

Fig. 21.



Experiments were also made to determine what effect on the amount of light produced by so adjusting the carbons, that the front edge of the upper one was in line with the centre of the lower one. Fig. 21 shows such an adjustment, and is from a photograph taken while measuring the light produced from the small Brush machine, running at 1250 revolutions per minute, and resulting as follows:

Front,	2218 candles.
Side,	578 "
"	578 "
Back,	111 "
	$3485 \div 4 = 871.$

The light produced by the same machine, under the same conditions, except the carbons being adjusted in one vertical line, was 525 candles. This would seem to indicate that nearly 66 per cent. more light was produced by this adjustment of the carbons; but a close study of the conditions satisfies us that such is not the case, and that there is no advantage to be derived from such adjustment, except when the light is intended to be used in one direction only.

TABLE I.

SHOWING WEIGHT, POWER ABSORBED, LIGHT PRODUCED, ETC., BY DYNAMO-ELECTRIC MACHINES TESTED BY A COMMITTEE OF THE FRANKLIN INSTITUTE, 1877–8.

NAME OF MACHINE.	Weight in pounds.	COPPER WIRE IN				Revolutions of Armature per minute.	Foot-pounds of power consumed.	Horse-power.	LIGHT PRODUCED IN STANDARD CANDLES.		Foot-pounds of power consumed per candle light.	Size of carbons.	LENGTH OF CARBON CONSUMED PER HOUR.	
		ARMATURE		FIELD MAGNETS.										
		Size.	Weight.	Size.	Weight.				Total.	Per h.-p.			+	−
Large Brush, .	475	·081 in.	32 lbs.	·134 in.	100 lbs.	1340	107·606	3·26	1230	377	87·4	$\frac{3}{8} \times \frac{3}{8}$	1·78	·34
Small Brush, .	390	·063 in.	24 lbs.	·096 in.	80 lbs.	1400	124·248	3·76	900	239	137·	$\frac{3}{8} \times \frac{3}{8}$	1·91	·58
Large Wallace,	600	·042 in.	50 lbs.	·114 in.	125 lbs.	800			823					
Small Wallace,	350	·043 in.	18¾ lbs.	·098 in.	41 lbs.	1000	128·544	3·89	440	113	292·	$\frac{1}{4} \times \frac{1}{4}$	2·45	·073
Gramme, . .	366	·059 in.	104 lbs.	·108 in.	104 lbs.	800	60·992	1·84	705	383	85·	$\frac{1}{4} \times \frac{1}{4}$	3·15	·55

We would here call the attention of those who may compare our results with those obtained at the recent experiments at South Foreland, England, to the following statement upon this point, in the report of Mr. Jas. N. Douglas, Engineer to the Trinity House, page 16 of the official report:

"I have found this arrangement of the carbons (the axis of the bottom carbon nearly in the same vertical plane as the front of the top carbon), and assuming the intensity of the light with the carbons having their axis in the same vertical line to be represented by 100, the intensity of the light in four directions in azimuth, say E., W., N. and S., will be nearly as follows:

East or front intensity, . .	287 to 100
North or side " . .	116 to 100
South or " " . .	116 to 100
West or back " . .	38 to 100
	$557 \div 4 = 139$ to 100."

* * * * * * * * *

' In measuring the candle-power of the light produced by each machine, I have given the mean intensity obtained in the direction of the photometer, the carbons in lamp working with the Holmes & Alliance machines being always arranged with the axes in the same vertical line, and the carbons in the lamp working the Gramme and Siemens machine being always arranged with the front edge of the top carbon nearly on the centre of the bottom carbon."

It is, therefore, evident that the results given by Mr. Douglas must be divided by 2·87 in making a comparison with those obtained by us.

Thus, in the table on page 31, official report, in the column headed Light produced by H. P. in standard candles, he gives for the Gramme machine condensed beam 1257, but if this be divided by 2·87 we have 438 candles, which is, no doubt, still too high, our result of 383 candles per H. P. for the Gramme, being obtained under the careful and rigid conditions before named.

[To be continued.]

Manufacture of Gunpowder without Water.—A commission was appointed in Russia in 1871, to study the question of the improvement of the powder used in rifled cannon. One of its members, Colonel Winer, taking up an idea once suggested by Saint

Robert, proposed to manufacture powder without employing water, and by compressing the materials at a temperature a little higher than that of the fusion of sulphur.

The advantages of powder thus prepared are as follows: (1) Its hygrometric property is diminished, and so it is less affected by remaining long in damp places. (2) The manufacture is less expensive, because drying rooms are dispensed with, and the mixture of the constituents takes place in mixing drums instead of mills. (3) The danger in manufacture is diminished. The powder being prepared directly in the dry state, only small quantities are treated at one time.

Winer was charged to make experiments in this direction in the works at Okhta, and he made the necessary arrangements for the purpose. The latter consisted of a hydraulic press, to which were adapted two hollow plates of copper, connected by two pipes of the same metal for the passage of steam. The lower plate was screwed on the plate of the press, which was fixed on the piston, and communicated, through a caoutchouc tube, with the steam pipe. The upper plate was fixed, and put in communication with the steam pipe by means of an iron pipe. The pulverulent and dry mixture, prepared in the drum, was spread uniformly on the lower copper plate, then the piston was set in motion, and pressure was produced for ten minutes. The disk of powder thus obtained was a perfectly homogeneous mass. The temperature of the steam was about 120° C. With a pressure of 130 atmospheres, measured in the manometer, cakes were got with a density of 1·80 to 1·9; with 30 atmospheres, it was 1·66 to 1·7. These pressures correspond respectively to 114 k. and 25·4 k. per square centimetre. The cake was reduced to grains by means of crushing cylinders. By means of a sieve the grains were isolated from the rest of the powder; and lastly were discharged into bags.

Only in 1874, after having experimented with a long series of compressed powders of different grain and density, did Winer find one which answered the requirements. This powder had a density of 1·6, a grain of 6 to 8 mm., and gave with a charge of 2·250 k. in a range 4-piece, an initial velocity of 471·5 mm. in the projectile. The tension of the gas was 1366 atmospheres.—*The Iron Age.*

FUTURE WATER-SUPPLY OF PHILADELPHIA.

By Henry P. M. Birkinbine.

In the last fifty years great improvements have been made in the sanitary condition of cities, and with the most satisfactory results; so that not only the comfort and convenience, but the health and longevity of these crowded centres of population have been greatly promoted.

The marked success which has attended the introduction of a copious supply of water and drainage by systems of sewers, has increased the interest in such matters, and led to great earnestness and activity in the investigation and application of these important means of sanitary improvement; so that at the present time every town of any pretensions has availed itself of either a water-supply or system of underground drainage, or both combined, or is seeking information on these subjects. Philadelphia, in these, is not behind any other city in the country. It is true there are defects in our present arrangements to be corrected, and much yet to be done to make them complete; but in their present condition they will compare favorably with most of the larger cities. The water-supply has been ample, completely distributed, and, until lately, of a satisfactory character.

A city of the magnitude, wealth and population, present and prospective, of Philadelphia, must not be satisfied with merely meeting present wants, and making arrangements to supply them as the emergency arises; but a proper and judicious foresight must be employed in designing and carrying out its systems of water-supply and drainage.

The question proposed for discussion in this paper is the future water-supply of Philadelphia. This has occupied considerable attention, and a number of schemes have been presented to the consideration of Councils and the public. Among these are:

1. Increasing the water-power at Fairmount.

a. By store dams to keep up the flood water, and utilize it for power in times of drought.

[1] Paper read before the Franklin Institute, February 20th, 1878.

b. By purchase of the power created by "Flat Rock" dam.

c. By raising Fairmount and Flat Rock dams.

2. Pumping the water from the Delaware and Schuylkill by steam machinery, by increasing the number and power of the pumping engines.

3. Bringing the water from the Delaware at Lambertville to near the city by gravitation, and pumping it into the reservoirs by steam.

4. By gravitation, either from the Delaware River, or the Perkiomen Creek, a tributary of the Schuylkill.

Quality of Water.

Next in importance to the character of the air we breathe is that of the water we drink; therefore, in considering a water-supply, there is no question of such marked importance as the comparative purity of the source from which the supply is drawn. No matter how much the cost of securing better water may exceed that required to furnish an inferior quality, the expense should not be permitted to interfere, so long as it is in the power of the city to meet it. So with any other sanitary improvements, money considerations should never weigh against health and longevity.

The question of what constitutes good potable water, is one which has generally been left to the chemists to examine and decide; but they differ in their method of analysis and conclusions arrived at, and confess that they are unable to decide by analysis alone. Messrs. Booth and Garret, in their able report on the chemical examination of the waters of the Delaware and Schuylkill, made to the Commission of Engineers, say: "We may as well confess that chemists are uncertain as to the nature of the organic matter which causes the unhealthiness of a water.[1] Chemically pure water is not attainable from natural sources. Rain water takes up impurities in its passage through the atmosphere; springs, wells, brooks, rivers, and lakes, all contain mineral salts and organic impurities, dissolved by the water in passing through the earth, or over their drainage areas. Most of these may be discerned and their character and amount determined by analysis; but to obtain the best results, a noted chemist has stated,

[1] Report on the water-supply of the city of Philadelphia, made by the Commission of Engineers, 1875, page 108.

in substance, that nothing exceeds a critical examination of the drainage of a given source; for by a knowledge of the geology, topography, physical and commercial features of the water-shed, the quality of the water obtainable from it is best determined."

The character of the future supply for this city is thoroughly and ably discussed by Julius W. Adams, C. E., one of the commission upon the water-supply of Philadelphia,[1] and to this report I would refer those who desire to examine the subject more at length.

A special committee of the Commissioners of Fairmount Park reported upon "*The Preservation of the Purity of the Water-Supply,*" and presented the report to the public in a pamphlet, in 1867. It is to be regretted that many of the statements and figures of this report cannot be relied upon; and yet it contains matter of importance in the discussion of this subject. On the first page there is the following statement:

"The superior quality of the water of the Schuylkill at Philadelphia, chemically considered, *when free from impurities introduced by human agency*, cannot be doubted; all analyses yet made place it in the first rank as a water proper and desirable for the ordinary domestic uses."

To sustain this assertion of the chemical purity of the water, a table is inserted on page 4, by which it is proposed to show that the water supplied to Philadelphia from the Schuylkill is better than the average of the cities noted in this table; but there are errors in this table, which, when corrected, do not sustain the assertion. So far as chemical analysis exhibits anything of the nature of the water of the Schuylkill, it shows a steady increase in the amount of solid matter to the gallon, evidently introduced by human agency. Thus in the analysis of the water made in

1842	there were	4·42	grains	to	the	gallon (Boye).
1850	" "	5·50	"	"	"	(Silliman).
1854	" "	6·10	"	"	"	(Booth and Garrett).
1862	" "	7·04	"	"	"	(" ").
1875	" "	8·183	"	"	"	(Cresson).

But the relative amount of solid matter alone per gallon does not form a reliable indication of the value of the water for drinking and household purposes.

[1] See Report, 1875, pages 57 to 100.

The character of the material from which the solid matter is derived, and the condition it may be in when the water is presented for use, are the only proper standard for judging of its value. But there is frequently great difficulty in detecting the presence of deleterious matter in water. It may be perfectly limpid, and, to the eye, satisfactory, and yet contain objectionable matter. So with all the other means of examination.

The method above suggested, of an examination of the drainage area, is practically the best means of judging of the fitness of the water for a public supply for a city.

Schuylkill.

The water of the Schuylkill, when free from objectionable matter introduced by the agency of man, cannot be surpassed in desirableness for all purposes presented by the wants of a large city. As a supply for Philadelphia it is inexhaustible, even at its lowest stages. Its smallest flow during the seasons of extreme drought may be set down as about 200,000,000 gallons per day: four times the present requirements of the city.

The drainage area of the Schuylkill above Fairmount dam is as follows:

Schuylkill	County,	324	square	miles.
Berks	"	841	"	"
Lebanon	"	43	"	"
Lehigh	"	73	"	"
Montgomery	"	396	"	"
Bucks	"	82	"	"
Chester	"	161	"	"
Philadelphia	"	22	"	"
	Total,	1942	"	"

The water from Schuylkill County is entirely from the sandstone formation of the coal measures, and is almost free from mineral salts of any kind, except that pumped or flowing from the coal mines. The character of this mine drainage and its peculiarities has been so often described, and the means of correction by the lime water in Berks County, that it need not be repeated here.

One of the conclusions arrived at, in the special report of the Park Commissioners, is: "That the amount of acid caused by the coal

mines has probably reached its maximum." That this is not the case will be demonstrated by the following considerations:

The mine refuse, of which there are immense quantities about the mines, contains pyrites, which furnishes the acid water. These heaps of mine waste are constantly being disintegrated by the action of the elements, and washed into the stream. The bitter water from the old abandoned mines continues to flow. When the upper veins are worked out, shafts have been and are being sunk to work the underlying veins. The workable veins have not all been developed, and new mines are and will be opened; so that the maximum has not been reached.

The mine water in times of drought seems to be making its way down the river, and its presence may be observed from the cars, in the Big (Lewis's) dam below Reading, by the light blue color of the water, and the deposit upon the wood-work of the dam.

The limestone water which forms so large a part of the streams coming in in the vicinity of Reading, produces no deleterious results; in fact, it is beneficial in correcting the acidity of the mine water.

The washings from the other mines, which are principally iron, from railroad cuttings and embankments, and from plowed fields, so far as they are merely mineral, are only objectionable from the fact that they render the water turbid at times.

The objectionable feature of the water is derived from organic matter; from cultivated fields, factories, stables, and house drainage. It is difficult to estimate either the quantity of this which finds its way into the river, or the proportion that ultimately reaches the water-works, or the condition the objectionable matter may be in when it arrives at the works; all these are important considerations, but most difficult of solution.

By the census of 1870, there was a population of 340,790 living on the drainage area of the Schuylkill above Fairmount dam. Allowing an increase of about 15 per cent., it would make the present population 400,000. One-half of these reside in the cities and larger towns, and would give an average of about 200 to the square mile. The population living on the area drained by the Thames, England, from which the city of London procures its principal supply of water, is 270 to the square mile. Notwithstanding the means resorted to by many of the towns in the drainage area of the Thames for utilizing their sewage, or purifying it, and the large expenditures the

companies taking water from the river have incurred of late years, for subsiding reservoirs, filter beds, and store reservoirs, to purify the water, the Board of Public Works of London are again considering the subject of securing a supply of better water from some other source, if only for drinking and culinary purposes.

With the return of business activity, there are few sections of our country which will become as densely inhabited as the drainage area of the Schuylkill; for none possess greater inducements for the locating of industrial establishments.

The Board of Health of the city of Reading, in their report, 1876, page 10, estimate the quantity of animal waste accumulating in the limits of the city in 24 hours, to be 2·51 tons of excrement, 25·14 tons of urine, 154·28 tons of liquid garbage. The population of the city at that time was 40,100.

Reading may be said to be without sewers; therefore, but a small proportion of this objectionable matter reaches the river directly; but the time has come when a complete system of sewerage for that city is a necessity, and surveys are now being made for the purpose of adopting a system of underground drainage.

Of the number of deaths in that city, 1118, during 1876, 412 are reported to have died from zymotic or preventable diseases.

These remarks in reference to Reading will hold good in the other large towns in the drainage area. So that while there may be little to fear at present from town drainage, what the future will be, can only be conjectured. What effect the river may have upon objectionable organic matter drained into it to render it innocuous, is a question of great importance, but undecided. It is claimed by some that the oxygen in the water acts upon the organic matter and destroys it (burns it up), leaving only the ashes, which subside and fall to the bottom, and that this is done in a short time, or during the ordinary flow of the stream of from eight to twelve miles. Others, of equally reliable authority, claim that when water is once contaminated by sewage, it is not fit for use, and that the flow of over one hundred miles will not restore it to its former potability.

This question occupied much of the attention of the Royal (British) Commission on the Pollution of Rivers, and the opinions of a number of experts are arrayed on both sides of the question. The evidence on the affirmative side—that is, that the water has in itself the power of self-purification after contamination, in a comparatively short

time—is collected, and can be found in a paper on the "Sanitary Chemistry of Water," Vol. I; Public Health papers of the American Health Association, by C. F. Chandler, Ph. D., M. D., LL. D. The position that there is danger in using the water after once being contaminated, is sustained by the collection of a large amount of evidence from the same reports of the commissioners on the pollution of rivers, and applied to the Schuylkill, by Julius Adams, C. E., in the report on the water-supply of the city of Philadelphia, made by the commission of engineers. The evidence on both sides is supported by chemical tests, experiments and observations, principally upon the River Thames, from which London draws most of its water-supply. Dr. Charles M. Cresson, in his analysis of the Schuylkill water, gives as one of the results: Sewage, 0·2142 grain to the gallon. Booth and Garrett object to the use of the term, and deny the presence of sewage in the Schuylkill water.

The most objectionable drainage into the river is that of Manayunk, because of quantity and close proximity to the intake of the different works. This consists of house and factory drainage, and amounts, in extreme dry seasons, to more than one-twentieth of the entire flow of the river. Of this drainage, that from houses, although it forms the smaller part, is the most obnoxious.

The subject of getting rid of this objectionable matter has occupied much attention, and several schemes have been suggested, the latest by the Chief Engineer of the Water Department, in a proposition, in his last report, to intercept all the drainage above the canal, and convey it by a sewer to the Delaware. No estimate of the cost of this work is given. It will be between six and seven miles long, and principally tunneling; but it will only intercept the drainage above the canal, leaving almost the entire factory drainage and some of the town still flowing into the Schuylkill. The character of the factory drainage will be exhibited by an analysis made by Dr. Charles M. Cresson, of one of the largest and most objectionable contributors. The quantities are in pounds per one million gallons of discharge: Ammonia, free, 48·57 lbs.; albumenoid, 206·42 lbs.; from nitrates, 29·14 lbs.; sewage, 2064·28 lbs.; sulphuric acid, trace; chlorine, 388·57 lbs., or more than one ton per million gallons—2737 lbs.

The character of the water in the Schuylkill has changed greatly in the past fifteen years, and even to the unaided senses of sight,

smell and taste, has perceptibly grown more impure. Chemical analysis sustains this, as shown above.

The River Schuylkill takes its rise in the Broad Mountains on the north, and the water-shed has its divide between it and the Lehigh, near Topton, on the East Pennsylvania R. R., and between it and the Susquehanna, near Lebanon, on the Lebanon Valley R. R.

The navigation company has constructed store reservoirs upon the upper waters: Silver Creek, 1500 feet above tide, containing 42,780,500 cubic feet; Tumbling Run, lower dam, 647 feet above tide, storage capacity 25,546,512 cubic feet; upper dam, 694 feet above tide, storage capacity 39,858,612 cubic feet.

The Pottsville Water Company have also two store reservoirs; the higher and larger, on Eisenhuth's Run, at an elevation of about 1700 feet above tide, will store about 52,000,000 cubic feet. The navigation of the river has been improved by a system of canals and dams reaching, at present, from Fairmount dam to Schuylkill Haven. In former times the canal extended up to Port Carbon; but the upper portion, above Schuylkill Haven, has been abandoned, on account of the washing of the waste material from the mines into the canal and pools, the number of locks and scarcity of water. The Union Canal follows the Tulphehocken its entire length. There are several store reservoirs for feeding the upper levels. The principal supply of the summit level is pumped from the Quittapahilla and Swatara, on the other side of the divide between the water-shed of the Schuylkill and Susquehanna.

The mill-sites in the streams flowing into the Schuylkill are generally improved, and furnish power for saw-mills, grist-mills, and factories of various kinds.

The effect of the numerous dams upon the water is important in the consideration of the purity of the stream or its correcting power. The pools receive and retain much of the solid matter washed into them; they also allow much of that which is held in suspension to deposit, and the water to flow off bright and clear. Matter held in solution may be in part dissipated by chemical action, produced by the oxygen in the water, light and air; but how far this is the case, we have no positive means of ascertaining.

The alluvium collected in these dams and pools contains a large percentage of organic matter in various stages of decomposition.

Some idea of its character and amount may be formed from the deposits in Fairmount pool, from Columbia Bridge to the dam. This amounted, by actual hydrographical surveys between 1861 and 1864, to 3,313,681 cubic feet; and between 1864 and 1866, to 6,642,584 cubic feet, or an average of 5430 cubic feet per day for the five years.

The effect of flowing through the canal, and the traffic of the boats, cannot be of any advantage to the purity of the water.

There are three conditions in which to consider the river:

1. That of its minimum flow in times of drought.
2. That of its mean flow when free from storm water.
3. That of its maximum flow in times of freshets.

The Minimum Flow of the River at Fairmount is estimated by Mr. James F. Smith, chief engineer of the navigation company, to be 245,000,000 gallons; measurements made in September, 1874. By my own calculations, I have several times estimated the minimum flow of the river, and found it about 200,000,000 gallons. My estimates were made from the water used as power, and that pumped at Fairmount, and the amount used for passing boats through the locks, and the estimated leakage. This calculation is sustained by using the ascertained minimum flow of the Croton, 0·3 cubic foot per second, from 1000 acres. This would make the amount, for the Schuylkill, 241,000,000 gallons per day. From this must be deducted the evaporation for the summer months, 0·115 inch, from the surface of the river, dams and pools, making a reduction of 40,000,000 gallons, leaving about the minimum as per my calculations. In the forty days ending September 16th, 1876, the calculated average flow of the Schuylkill was 230,788,880 gallons per day. During this time there were, no doubt, days when the flow fell below 200,000,000 gallons per day. These calculations were made by the Water Department, upon the same basis I used.

Mean Flow of the River.—The measurements and estimates of the mean flow of the stream generally agree. The first of these were made by Rittenhouse, early in the present century, for the purpose of ascertaining the value of the river for navigation purposes, and corresponds with the measurements of others and my own, and makes the mean flow of the stream, when free from storm water, 650,000,000 gallons per day.

MAXIMUM FLOW.—By a comparison of all the available tables of rain-fall, kept in the drainage area, the yearly average may be taken as 45 inches. A part of this is evaporated, a part absorbed by vegetation, another portion may go to feed perennial springs beyond the drainage area of the river; so that the amount which reaches Fairmount is about 18 inches of the entire precipitation. This would give a mean daily flow equal to 1,665,000,000 gallons. Over 1,000,000,000 gallons of this amount pass over the dam in times of freshets; sometimes in quantities beyond our ability to calculate. The mean daily flow would all be passed over Fairmount dam with a depth of 10 inches on the comb of the dam. Sixteen inches would vent the average for two days in one. Beyond this we have no reliable formula by which to calculate the amount discharged over the dam. Oct. 4th, 1869, there was a depth of 11·46 feet above the comb of the dam.

While the mean flow of the river has maintained itself the same for over sixty years, the maximum and minimum have been farther removed from each; that is, in low stages of the river the amount has decreased, and the freshets have been more frequent, and the volume of water brought down much greater.

The records of the rain-fall kept in the vicinity of this city, for over fifty years, show marked increase in the precipitation every decade.

As a proportion of the water falling upon the drainage area finds its way into the river, there should be, and no doubt is, an increased flow in the stream; but as this increase passes off in floods, it is of no practical value for power. Many of the water-powers in the drainage, once improved and utilized, are now abandoned and allowed to go to ruin. This change in the character of the river may be accounted for by the cutting off of the forests, which formerly held back the rain water, by roots, mosses and undergrowth, and allowed a larger proportion of it to find its way into the soil, to replenish the perennial springs. This water now flows directly off, and, as a consequence, instead of a steady flow into the river and its tributaries, they are yearly assuming more the character of a torrent, subject to frequent droughts and to frequent floods.

At times of freshets and floods, some of the matter deposited in the pools or dams is stirred up and carried down the stream, and

our water is frequently discolored and filled with matter held in suspension. Not all of this is innocuous mineral matter, but much of it is made up of organic matter in various stages of decomposition. The danger of an admixture of such organic matter, even when with a large volume of pure water, was shown at Chicago, at the time of a freshet in the river, in April, 1876. The water supplied to the city was so much affected, as to be perceptibly impure to all the senses, and the result was a marked increase of bowel complaints, some resulting fatally. The water continued impure for a week. When the large volume of pure lake water, to be contaminated, is taken into consideration, and the distance from the mouth of the river to the crib, or intake of the water-supply, the danger of using water with the smallest conceivable admixture of such matter is made manifest.[1]

There is no doubt but that the river grass, found in such abundance in many parts of the stream, during the summer, does much to purify the water. It is claimed that since its introduction into the rivers of England, it has had a most beneficial effect. It is a new thing there, and has been transplanted, by some means not now known, during the present century, and has found its way into many of the rivers.

From the above statements the following conclusions may be arrived at:

1. That, notwithstanding the large population upon the area drained by the Schuylkill, there is at present but a small percentage of sewage drained directly into it from the large towns.

2. That sewerage has become a necessity for all of the large towns, and will be speedily constructed; when a large amount of sewage will be discharged directly into the river.

A proposition is before the city of Philadelphia to divert a portion of the most objectionable town drainage from the river, viz.: that of Manayunk, above the canal. This will do much to restore the river to its former condition of purity, but will only be a partial relief.

3. The most objectionable matter in the river is the organic matter which settles in the pools during its ordinary stages, but which is stirred up and carried down the stream in various conditions of decomposition during freshets.

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[1] Report, 1876, p. 65.

4. By cutting off the forests and clearing the ground, the minimum and maximum are further removed from each other. The river is more frequently low, and less water flowing in it, and is more frequently affected by storms, and, as a consequence, turbid.

5. That when the towns on the drainage of the Schuylkill construct sewers, the amount of sewage drained into the river will become a large portion of the stream; one-half of the town dwellers would discharge an amount equal to one-twentieth of the volume of the river in extreme low stages.

Delaware River as a Source.

The quality of the water furnished by the Delaware is unexceptionable. There are comparatively few towns of importance in the drainage area, and nothing of a character to deteriorate the water. If the water is taken between Trenton and Bull's Island, there are seasons of the year when it becomes objectionable, on account of the large amount of water abstracted from the river at Bull's Island, to feed the Delaware and Raritan Canal, leaving but a small amount to flow in the channel of a large river, and, as a consequence, stagnant pools of water occupy parts of the bed of the stream. In seasons of drought there is practically no water flowing in the channel below Scudder's Falls, where the Trenton Water-Power Company take the entire flow of the river. The water for some distance below Easton would be objectionable on account of the drainage of Easton and Phillipsburg, and the water of the Lehigh, which is subject to all the objections presented against the Schuylkill. If the water for the supply of Philadelphia is obtained from the Delaware, it should be taken either above Easton, at Bull's Island, or at some point in the tidal portion of the stream, as near the city as it is possible to come, and evade the influence of the city sewage. The greater volume of water in the river between Trenton and Philadelphia, and its constant motion by the ebb and flow, will do much to maintain its purity. Therefore, with the exception of that portion of the stream between Trenton and Bull's Island, and a short distance below Easton, the river furnishes an abundant supply of unexceptionable water for all possible future demands of the city.

The Perkiomen as a Source.

Character of the Water.—The Perkiomen is the largest tributary of the Schuylkill. The country drained by it is well adapted for collecting water for the supply of a city, the formation being principally trap and sandstone, with from 8 to 10 square miles of lime. There are also some iron mines, now worked, near Boyertown. The old copper and lead mines are below the point where the water would be taken. There are no manufactories which would impair the character of the water, and no towns of any importance in the drainage area. The country affords no inducements for industrial establishments, nor is it likely to become thickly settled. The number of inhabitants has been slightly augmented by the construction of the railroad, but, with this exception, there has been but little, if any, increase of population in the last fifty years. Nearly one-third of the entire drainage area is still wooded, and likely to remain covered with timber. The soil is of little value for tillage. A large proportion of the cleared land is kept in grass, milk and butter being the principal products of the country.

The commission of engineers, in their report upon the water-supply of Philadelphia, in referring to this source, of which they made personal examination, say that it is free, and likely to remain free, from causes of pollution, p. 38. The Park Commissioners claim that "the Schuylkill can be better protected from pollution than streams of smaller size which have been proposed to supply the city," p. 9. This is the only statement made by any who have examined this source, which reflects upon its desirableness, so far as the quality and maintenance of the purity of the water are concerned. Storing of the water in large reservoirs would tend to purify it. All matter held in suspension would sink, and the action of light and air would do much to dissipate organic impurities.

Quantity.—The public generally have doubted the capacity of this stream to furnish an adequate supply for the future demands of the city. The natural flow of the stream would not meet the present demand in seasons of drought. The minimum flow of the stream, using the same bases for estimating as were used for the Schuylkill, is 30,000,000 gallons per day. To utilize a stream of the character of the Perkiomen, impounding reservoirs are necessary, so that the flood water may be stored to supply deficiencies in times of drought.

The Perkiomen takes its rise in the South or Lehigh Mountains, which have an elevation of from 900 to 1000 feet above tide. Where the proposed dam would be located, a trap-dike crosses the valley, and probably stops all the water flowing in underground channels; so that the entire rain-fall upon the drainage area, except that absorbed by vegetation, or lost by evaporation, passes this point. The available drainage area is 220 square miles; from this area the mean daily flow of the stream past the location of the proposed reservoir, by carefully made estimates of William J. McAlpine, C. E., shown in a table, p. 132, report of commission of engineers, is an average of 311,000,000 gallons per day. Using the data presented by the special committee of the Park Commissioners, for the mean daily flow of the Schuylkill past Fairmount dam, applied to the flow of the Perkiomen at the proposed store reservoir, the daily average flow is 250,000,000 gallons per day. My own estimate, as shown in my report to Councils, 1866, p. 21, is 240,000,000 gallons per day. In Mr. McAlpine's estimate, he utilizes from 20 to 90 per cent. of the rain-fall, dependent upon the season of the year, making an average of 59⅛ per cent. of the annual precipitation, or 28·41 inches. My estimates are based upon 23·12 inches of rain-fall made available for city supply.

The commission of engineers, by taking the lowest average rain-fall for 20 years, and making every allowance for possible loss, make the minimum flow 160,000,000 gallons per day. My own estimates, taking the lowest recorded annual precipitation in Philadelphia (1848), and estimating 50 per cent. utilized, would give a minimum daily average of 183,000,000 gallons. It may, therefore, be confidently asserted that this source alone will furnish an abundant supply of unexceptionable water for a city of over 2,000,000 inhabitants. Should a demand greater than this ever arise, the East Perkiomen, and Skippack, large tributaries entering the main stream below the proposed dam, could be intercepted and utilized.

In giving the above data, I have purposely laid stress upon the opinions of those who have critically examined the source, and used them to demonstrate the correctness of the position I assumed when acting as Chief Engineer of the Water Department in 1864. I recommended to the Councils of the City of Philadelphia the utilization of the Perkiomen by gravitation, as the best and most economical source of future water-supply.

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. PICTET.

[Translated for the JOURNAL OF THE FRANKLIN INSTITUTE, by P. PISTOR, M. E.]

In order to facilitate the perusal of these memoirs, they have been divided into six chapters; each treating of a special subject of this investigation.

The first chapter is devoted to general remarks. Therein we develop the object of these memoirs and the physical laws relating to the change of condition of a body. The second chapter contains a description of the apparatus employed. The third chapter gives the experiments themselves. The fourth chapter is devoted to calculations for the reduction of the observations; a determination of the density of liquid oxygen, of the lowest temperatures and highest tensions of the vapors of liquid oxygen. The fifth chapter is devoted to hydrogen. The sixth chapter gives the conclusions which may be drawn from these experiments and their results.

I. GENERAL REMARKS.

All the phenomena of heat were originally revealed to man through the medium of the sense of touch.

The sensation of heat and cold, born of the peculiar modality of the sense of touch, was first attributed to a special fluid, phlogiston, or heat distributed in different degrees through all bodies. This theory, admitted for many centuries, was the outgrowth of the hypotheses then advanced on light, and had to be almost forcibly displaced from the rather analytical minds which guided science at that time.

But gradually several categories of phenomena were ranged in the chapter of heat, although the sense of touch was completely excluded from the study of these manifestations of heat. Calorimetry took birth as well as the study of the change of condition of bodies. The term, latent or insensible heat, still remains in scientific literature, and

defines well that particular phase through which the human mind has passed.

The new path opened to investigation a field so rich in discoveries of all kinds, that all human knowledge may be said to have profited by it.

The mechanical theory of heat, which has resulted from it, complete, is an immense work, in which philosophy as well as physics and chemistry have found a rich harvest of facts and interpretations of indications, which have thrown a strong light on the chaos in which investigators formerly blindly groped.

This magnificent discovery consists in completely ignoring phlogiston, or heat as a body, and in explaining it by the movement of the particles constituting the body.

The study of heat has become the study of motion; the closely related motion of atoms, of invisible molecules, which cannot be distinguished by the microscope, but can be demonstrated to-day in as satisfactory a manner as if it could be seen.

The battle-ground has thus been entirely transferred, and the study of the constitution of bodies has become an essential requirement to the study of heat. These two chapters are inseparable, and should be treated together.

The theory of gases, so admirably developed by M. Clausius, is one of the most remarkable and immediate results of this scientific progress.

The object we pursue in this pamphlet is to make use of the mechanical theory of heat, which has already become classical, in explaining several anomalous or seemingly anomalous phenomena, which appear to be more or less contradictory to the general laws of physics, or to the theory of M. Clausius; and to bring them back to phenomena of the same nature, showing no contradiction to the above cited laws, by the experimental method.

In order to put the question in a precise manner, we will describe the phenomena we see in a few words.

Almost all known bodies are susceptible of passing through the three conditions: gaseous, liquid and solid. For the same body, these three conditions require different temperatures. The solid condition corresponds to the lowest temperature, the liquid to a higher, and the gaseous to a still higher temperature.

It is consequently assumed that the particles constituting the body, called molecules and atoms, attract and have a tende ncy to approach each other, but that an opposing force resists this tendency and counteracts this attraction. This force is the "caloric motion" which is dependent on the temperature.

This general law involves the assumption that all bodies, without exception, are constituted in an analogous manner, and that all the constituent particles are subjected to the forces of cohesion and the motion of heat.

From which may be deduced, that if the heat diminish gradually in a gaseous body, the molecular cohesion will forcibly conduct it into a liquid or solid state; or else the hypothesis of the general application of the law would be erroneous.

M. Regnault, in his memorable experiments on the compression of gases, has thrown light on an important point: all compressed vapors, on approaching their point of liquefaction, compress more than is indicated by the law of Mariotte and Gay-Lussac; a law which applies to an ideal, absolutely perfect gas.

This result evidently shows that the molecular forces, perhaps cohesion, aid the pressure in order to bring still closer together the free molecules, which are within the sphere of reciprocal attraction, ready to precipitate themselves as liquid drops.

The vapors of all known fluids—the vapor of mercury, of water, of alcohol, of sulphuric acid, of carbonic acid—pass through the same phase; they all compress more than would a perfect gas.

Only the so-called "permanent gases" do not pass through this phase peculiar to vapors, named thus to distinguish them from perfect gases. They even show a contrary result under the action of strong pressures; that is, they compress less than the law of Mariotte and Gay-Lussac would require. M. Regnault has shown that hydrogen in particular is appreciably less compressible than nitrogen and oxygen; the last two gases follow the law of Mariotte almost absolutely, with but the slightest variations for pressures of 30 and 50 atmospheres.

If the difference observed between the volume of a body at a given pressure and temperature, and the volume which it should occupy if the law of Mariotte and Gay-Lussac were strictly true, be called the "co-volume," we find that the co-volume of vapors is always

positive, whereas that of the permanent gases is almost zero or is negative.

Adopting these results as a basis, and admitting M. Clausius' theory of the constitution of gases and vapors, we are obliged to acknowledge that certain molecules, though very close, tend rather to repulse than to attract each other; as the tension increases more rapidly than the calculation would indicate, assuming the cohesion to be equal to zero.

For a difference in volume of $\frac{1}{2}$, that is, on compressing a gaseous mass, whose volume is one, and reducing it to a volume equal to $\frac{1}{2}$, the pressure has more than doubled for the permanent gases, but for vapors is less than double the initial pressure.

It is evident that these results form a powerful argument against the universality of cohesion, which accordingly would be but an accidental force, peculiar to certain bodies, and might even be replaced in some cases by a repulsing and opposite force.

M. Natterer, Professor of Physics, at Vienna, has endeavored to determine experimentally, to what point the so-called permanent gases might be compressed, and what would be the influence on the volume, of enormous pressures, which might even reach 3000 atmospheres. By means of this gigantic power he hoped to accomplish a change of condition, owing to the very considerable approach of the gaseous molecules towards each other. Had the cohesion of the gaseous particles been but ever so slight, it would seem, on first consideration, this change should have taken place. The following are some of the figures obtained by M. Natterer from his experiments, made in 1854, following the observations made by M. Regnault.

Hydrogen, Oxygen and Nitrogen.

M. Natterer has subjected hydrogen, oxygen and nitrogen to pressures varying from that of the atmosphere, to one of 2790 atmospheres. He conducted his experiments in the following manner:

He introduced successively into the same enclosed space, equal volumes of hydrogen, for instance, 10 volumes equal to the initial one. A peculiar and very sensitive manometer indicated the corresponding pressure. In the following table the first column gives the volumes of gas compressed into the volume of the first one. The second column gives the recorded pressures in atmospheres; and the third gives the differences between each two succeeding pressures.

HYDROGEN.			OXYGEN.			NITROGEN.		
Volume.	Atmosphere.	Difference.	Volume.	Atmosphere.	Difference.	Volume.	Atmosphere.	Difference.
0	0	8	0	0	7	0	0	5
8	8		7	7		5	5	
18	18	10	17	17	10	15	15	10
28	28		27	27		25	25	
68	68	10	157	157	10	75	75	10
78	78		167	167		85	85	
128	134	12	227	232	11	225	240	12
138	146		237	243		235	252	
238	274	13	277	287	11	275	306	15
248	287		287	298		285	321	
358	438	16	357	382	12	355	444	22
368	454		367	494		365	466	
418	539	17	417	463	16	415	600	30
428	556		427	479		425	630	
458	608	19	457	539	24	455	729	35
468	627		467	563		465	764	
488	665	20	487	614	27	485	840	42
498	685		497	641		495	882	
538	775	24	537	764	36	535	1095	64
548	799		547	800		545	1159	
598	930	28	597	1010	46	595	1546	94
608	958		607	1056		605	1640	
668	1134	30	647	1284	70	645	2046	110
678	1164		657	1354		655	2156	
758	1434	37				675	2394	128
768	1471					685	2522	
828	1701	40				695	2654	136
838	1741					705	2790	
878	1904	44						
888	1948							
968	2044	54						
918	2098							
948	2277	70						
958	2347							
978	2505	89						
988	2594							
998	2689	101						
1008	2790							

Let us examine the three gases: Oxygen only reaches a pressure of 1354 atmospheres, the highest limit attained with that body.

The above table proves, in a very striking manner, that the law of Mariotte is absolutely false, as soon as a pressure of 100 atmospheres has been exceeded, and that is the case for all three gases examined. For relatively moderate pressures, oxygen follows the law of Mariotte the most closely, better than hydrogen. For higher pressures, on the contrary, the deviations are strongly marked, and when 657 volumes of oxygen have been compressed, the pressure, which theoretically should be 657 atmospheres, is equal to 1354 atmospheres, more than double.

Under the same conditions hydrogen shows a pressure of 1104 atmospheres, and nitrogen of 2156. It is evident from these figures that gaseous molecules must repulse each other with considerable energy, as an increase of 10 volumes of oxygen causes an increment of 70 atmospheres of pressure, and of 110 for nitrogen.

Interpreting these results by means of a curve, whose abscissæ represent the compressed volumes, and whose ordinates represent the corresponding pressures; they clearly indicate a manifest tendency towards a limit of compressibility which cannot be exceeded. This limit corresponds to that point of the curve, for which the ordinate becomes an asymptote; then the pressure increases indefinitely for a very small increment of gas, introduced into the original volume. That is, probably, what should happen, when the molecules of gas had been forced into absolute contact by the simple act of compression. The inter-molecular spaces becoming zero, all diminution of volume is impossible on account of the impenetrability of matter.

These conclusions, based on incontestable facts, seem to invalidate the universality of cohesion in a serious manner. According to these experiments it would seem, as M. Clausius explains it, that the molecular cohesion of all the permanent gases was zero, and that the deviations from the law of Mariotte, such as we have just witnessed, have their original cause in the material volume of the molecules, their thickness or diameter.

In vapors, on the contrary, cohesion exercises its power, even under slight pressures, and would cause an inverse deviation from that observed in comparing vapors with permanent gases.

It is essentially these phenomena which we wish to investigate more thoroughly; based on the experiments of MM. Regnault and Natterer, and on the theory of M. Clausius, besides using a previous

work on the relations existing between the different physical and chemical properties of volatile liquids.[1]

It is shown in the work quoted, that "for the same temperature, the cohesion of all fluids is the same;" that is, the molecular forces which bind two atoms or two molecules of any liquid together, are equal, if the temperature is the same for all the liquids. This theorem may be expressed in the following manner: if we take all the volatile liquids at one and the same temperature, and calculate the work required to tear an atom, α, from any liquid, at this temperature, and to free it from the force of cohesion which holds it, the work expended will be the same for all liquids, without exception.

This law proves that the fluid state does not manifest itself indistinctly, however great may be the force of cohesion. This cohesion must represent a certain force, K, operating at a distance, l, between two molecules, in such a manner, that the work of condensation or evaporation corresponds to that constant quantity for a temperature, t. Without this essential condition, liquefaction would be inexplicable.

The only known force which directly opposes cohesion is heat. It is admitted that it imparts to the constituent elements of bodies vibratory oscillations, whose amplitude is a function of the temperature.

A number of conclusions, drawn principally from the variations in the latent heat, such as are furnished by the tables of M. Regnault; laws which link the tension of the vapors to the temperature; the laws of expansion, etc., etc., lead me to advance the hypothesis: that the temperature, following a simple function, is directly proportional to the amplitude of the calorific vibration.

Taking a very small fraction of the millimetre as a unit, similar to that used in measuring the undulations of light, it would be found that an oscillation of a double amplitude would correspond to double the absolute temperature; an oscillation of triple the amplitude would give a temperature three times higher. Absolute zero would correspond to a length of oscillation equal to zero; as, for instance, a pendulum that had been arrested.

This definition of temperature agrees with what we previously asserted.[ii] It consists in assuming that the temperature of a body is absolutely determined, if the dynamic potential of the same, between

[1] *Archives des Sciences, phys. et nat.*, Jan. 1876, t. LV, p. 66.

[ii] Société de physique et d'histoire naturelle de Genêve Séance de Jeudi, 20 Décembre, 1877.

any temperature t' taken as a starting point, and a variable temperature t, always given by the dynamic equation into which it enters, be known.

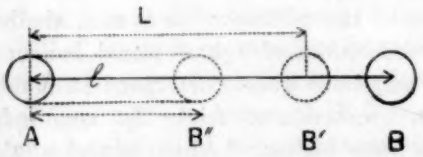
The computation of the tension of the vapor of water, based on this theory, agrees, within one mm., for all temperatures between 200° and 0°. We therefore think that we can adopt this equation as probably correct, and consider it as the measure of the amplitude of the calorific motion.

Does this imply that when a body has a temperature of $t°$, all the particles of the same, without exception, will vibrate in such a manner, that the amplitudes are all exactly equal? By no means. On the contrary, certain vibrations interfere with each other and produce sometimes longer, sometimes shorter, vibrations. The temperature of the body will correspond to the mean of all these elementary motions, and will represent the dynamic resultant of all the individual forces which constitute the store of work accumulated in this body; which store we call its potential.

This manner of explaining the action of heat can be demonstrated experimentally, by the change of state, of liquids into vapors, and *vice versa*.

Let us take any vapor under a pressure P, and at a temperature t. Under these conditions the inter-molecular interval which separates the free molecules of vapor, is inversely proportional to the number of these molecules. For double the number, the interval will be one-half.

Fig. 1.



Let K represent the energy of cohesion at the temperature t, a constant for all liquids; and let l be the amplitude of the calorific oscillation, corresponding to the temperature t. The annexed cut represents two molecules of this vapor, taken at the pressure P, and at the temperature t. The distance of the molecules A and B apart is $A\,B$, and this distance may be varied at pleasure by increasing the pressure of the gas. Let L be the minimum distance through which the cohesion has sufficient energy to obtain the value K, and let $A\,B''$ be equal to l, the length of a calorific oscillation corresponding to the temperature t. We can now trace the phenomena which will occur, step by step.

It is evident at once that "cohesion cannot produce liquefaction" as long as the tension keeps the molecules A and B at the distance AB from each other, its power being inferior to K, the extreme limit. Consequently the vapor might be compressed, and a new quantity of gaseous elements introduced into the same volume. As soon as the tension has reached a value P', the distance AB will be reduced to AB'. Precisely at this moment, the cohesion having become equal to K, the molecule B would be precipitated on molecule A, and they would form a drop of liquid. The two molecules will develop great heat, as the first oscillation will be equal to AB', and a few instants later would be reduced to AB''. The work expended and transferred to the walls of the receptacle, represents, as "latent heat of condensation," the work of cohesion between the limits AB' and AB''. The difference in volume between the gas and the condensed liquid enables us to determine the ratio $\frac{AB'}{AB''}$. This change of volume is considerable for liquids of average volatility.

From the above, the simple operation of the law of Mariotte, and the law of molecular cohesion, we can readily explain the manner in which liquefaction of a vapor takes place. It must commence by the molecules approaching each other to within a certain limit, where the cohesion is sufficiently strong; then, from that moment, if the temperature is assumed as constant, the pressure will be so also, whatever may have been the quantity of vapor originally introduced into the same space; the pressure P' will be a maximum. The latent heat disengaged is a function of the distances AB' and AB'', and of the number of molecules condensed. It is consequently also equal to a value of K, corresponding to the temperature of condensation, $t°$.

We should find the explanation of all the phenomena connected with the change from a gaseous to a liquid state, if we successively examine all known vapors under the same conditions. Let us make this examination, chosing the fluids according to their volatility.

It will be admitted that the force with which two molecules attract each other, varies with the nature of the body. The less volatile a body, the higher its boiling point on the thermometric scale, the greater is the tendency of cohesion to reunite its constituent particles. We may also conclude that the distance at which the molecules of this body will attract each other at a temperature t, will be greater than the corresponding distance, under the same conditions, for two molecules of a more volatile liquid.

Let us take water and sulphuric ether, for instance, and compress their vapors at a temperature of 30°. The distance $A\,B'$ for water will be greater than that of ether; consequently, according to the law of Mariotte, the tension of the vapor of water will not be as great as that of the vapor of ether. The pressures will be directly proportional to their volatility. The distance $A\,B'$ corresponds to 31·548 millimetres of mercury for water, and to 634·80 for ether.

The tension is not the same for both liquids; however, the length of the calorific oscillation $A\,B''$ will be the same for both fluids after condensation. The latent heat disengaged, in both cases, will, therefore, be solely proportional to the number of molecules which will have transformed themselves into liquid, by means of cohesion, to a constant, K, dependent on the temperature, and to a function which gives the increase in the power of cohesion, with reference to the distances which separate the molecules A and B.

Comparing water successively with sulphuric ether, sulphurous acid, ammonia and carbonic acid, we see that the distance $A\,B'$, at which condensation takes place, diminishes more and more, the more volatile the liquid we choose. At 0°, water condenses at a pressure of 4 millimetres, sulphurous acid requires 1165, methylic acid, 1879, and, finally, carbonic acid requires almost 30 atmospheres.

It is evident that the more refractory a vapor, regarding condensation, we choose, the less will be the difference between the volume of condensed liquid and that of the vapor. This is important, as it proves, that the only variable element is the force of cohesion, dependent on the peculiar nature of the vapor.

We see from all that precedes, that two conditions must be fulfilled to accomplish the condensation of two gaseous molecules A and B:

1. To bring the molecules so near to each other that the distance $A\,B'$ may correspond to a minimum attraction equal to K.

2. It is necessary and indispensable that the distance $A\,B'$ should be greater than $A\,B''$, which is the amplitude of the oscillation due to the temperature.

For were the attraction of the gaseous molecules but feeble, and the amplitude of oscillation l corresponding to a temperature t larger than the distance to which the molecules must be brought, so that the force of cohesion may be K, then "liquefaction becomes impossible, as at this temperature t, the minimum length (l) of oscillation is too great to allow a change of condition.

The second condition thoroughly explains all the phenomena relating to the so-called permanent gases. To condense these gases, it does not suffice to subject them to enormous pressures; the amplitude of the calorific oscillation must be brought below AB'; and to do that, their temperature must be lowered, their heat abstracted so as to reduce their calorific motion to a minimum. AB'' then being very small, as small as possible, we may hope that the distance AB', at which the cohesion reaches the value K, will be larger than AB'' "Only under these conditions" is liquefaction obtainable. Up to the present time it has been believed that pressure and temperature were so allied that the one might always be substituted for the other. This is true within certain limits, which we have defined by this explanation.

It is possible to determine tables of the tension of the saturated vapors of almost all volatile liquids. These tables show the relation which exists between the increase of pressure and the temperature t. But they cannot possibly be determined for very high values of t; and experience has shown that at a certain temperature t, the liquid passes spontaneously into a vapor, without change of volume. Starting from this point, the liquefaction of vapors generated in this manner becomes impossible. For water this temperature is between 400 and 500 degrees; for ether it is lower; for sulphuric acid it does not reach 250°; for carbonic acid and the protoxide of nitrogen it is even lower; finally, for the permanent gases, hydrogen, oxygen and nitrogen, this point is below the usual surrounding temperature.

This explanation will now permit us to consider the law of cohesion as universal, and proves that in order to liquefy these gases, the indicated means are indispensable:

To employ a great pressure. To employ great cold.

These two aids are necessary, should be employed simultaneously, and can be replaced by no expedients.

The analytical discussion which has conducted us to this result will admit of numerous applications. All the laws which govern the changes of internal, latent and external heat, the tension of volatile vapors, the specific heat, mixtures of gases and vapors; in a word, all calorimetry and thermodynamics are included in the problem we have just investigated.

All these special applications will be found in a pamphlet now in course of preparation. Here we merely wish to demonstrate, experimentally, that the preceding deductions, concerning the permanent gases, are correct.

ON THE EROSIVE AND ABRADING POWER OF WATER UPON THE SIDES AND THE BOTTOM OF RIVERS AND CANALS.

By Clemens Herschel, Civil and Hydraulic Eng., of Boston.

The title of this paper will recall to the minds of most engineers some well known, but, as will be shown, somewhat too highly valued observations of the "Ci-devant Colonel au Corps Royal du Genie," Le Comte L. G. Nançay Dubuat, who experimented 100 years ago—more exactly, between 1780 and 1784. To some it may also recall the fervent appeals of Mr. Thos. Login, M. Inst. C. E., 1867-69, in behalf of this same and but feebly illuminated branch of engineering and hydraulic science. Compelled to consider the matter, in the course of his professional practice, the writer has drawn freely upon all the German, French, English and American authorities within his reach; and, as showing the great utility and deciding influence which such a study may have in the consideration of water-courses, a concise history of the engineering problem referred to is here given; this is no less than that of the Cape Cod ship canal, in the state of Massachusetts.[1]

The Isthmus of Cape Cod, plainly to be seen on most any map, or globe, even, that represents the United States, is in effect nothing but a huge mole, or pier—a sort of fence run out into the sea, that separates the "Bay shore" of Massachusetts, and the sea-coast of Massachusetts, New Hampshire and Maine to the north of that, from the rest of the United States. But this is not all; navigation around this obstruction is of a very hazardous kind, because of the many and concealed shoals all along the route through the sound, and also on the outside of the islands of Martha's Vineyard and Nantucket; and from the fact that there is no harbor, not even for small coasters, between the southerly and the northerly ends of the Cape; further, because the sailing directions around this cape make less than a right angle with each other, because of the rigor of the climate in the winter, on account of the danger of collisions in the narrow channels between the shoals and in fogs, and from other such causes.

[1] See also an article by J. P. Frizell, C. E., Journal of the Franklin Institute, 1871, on the same subject.

These difficulties may be measured by their effects, which comprise wrecks and losses of life and property to a remarkable extent. Thus, from 1843 to 1859, 17 years, there were 827 wrecks, of which a record could be found: 4 steamers, 40 ships, 71 barks, 191 brigs, 492 schooners, and 29 sloops; total losses, 500, partial losses, 327; average of the total losses (compiled from the records of 108 cases), $500,000 annually; average of the partial losses, $81,750 annually; loss of life, estimated at 30 annually.[1] For the ten years succeeding, 1859 to 1869, there were lost 13 steamers, 23 ships, 32 barks, 100 brigs, 446 schooners, and 3 sloops; total, 617 wrecks; total losses, 211, partial, 406. And all this on a length of steamer line of only about 160 miles. And, of course, these losses have their effect on the rates of insurance and the freight charges by vessels that pass the Cape.

It cannot be surprising, therefore, that the project of constructing a canal across the Cape should have frequently been spoken of, and, in fact, we find that ever since 1623, only three years after the settlement of the country by the prilgrims of Plymouth, the utility of going through or over the Cape, rather than going around it, seems to have been recognized, and that a canal has been contemplated for more than 200 years. It will not be necessary to give in this place a history of all the attempts that have been made to commence the construction of such a canal by public, as well as by private, means. Suffice it to say that 8 distinct efforts of this kind have been made, the last of these having been made in 1860. And now, lest any one will have found the explanation of this remarkable state of affairs in the topography of the country through which the canal is to pass, it will be proper to state at once that this topography is of the most favorable description. There is a valley running through the Cape at its narrowest part, precisely where it joins the mainland, at the head of "Buzzard's Bay," and where the distance from bay to bay, on line of this valley, is about seven miles and a half. The bottom, or intervale, of this valley, is some 600 ft. wide at its narrow est part, and is, in maximo, about 32 ft. above the controlling mean low water of the sea. The meaning of this phrase, "controlling" mean low water, being, that low tide in one bay is at a different elevation from what it is at the other, and the lowest low water is naturally

[1] From the report of the Legislative Committee of 1864. Some wrecks are included which should have been omitted; others were, no doubt, omitted, of which no record had been kept.

the "controlling" low water. The average depth of cutting, for a canal 18 ft. deep at controlling mean low water, would be only about 35 ft. The material, as shown by borings to the proper depth, and from all the other information that can be reached, is, throughout, nothing but mud, sand, gravel, and a few boulders. Two tidal creeks occupy this valley, and their head-waters nearly overlap each other. Every report that has ever been made upon this project has spoken of it in highly favorable terms, and has estimated that the enterprise would be a profitable one, viewed from a national and political-economical standpoint. Why, then, has this canal never been built? Why has it not been built since 1860-64, date of the last investigation upon the subject by the state of Massachusetts?

Of course, the answer to these questions may be variously enunciated, but a tolerably fair one to the last of the two questions may be given, though it seems almost laughable to say so, by reference to only these two sentences in the report of 1864: "We have already spoken of the locks required, in consequence of the different levels of the sea at the two extremities of the canal. The mean of the daily maximum variations in the elevations of the two basins" (occurring 4 times in the 25 hours) "is 6·5 ft." (should have been 5·23 ft.); "and such a fall in the distance of eight miles, must, we need not say, be kept under control." Further than by these words, the *question*, whether or not locks were a necessary part of the plan, was nowhere discussed, but it was *assumed*, as by the last phrase in the second sentence above quoted, that canal locks were unavoidable. But the same report takes care to say that the current to be produced in the canal will not be detrimental to navigation; it "would not exceed from three to four miles per hour; it sometimes reaches nearly three miles per hour off West Chop, where the tide-waves cross each other in eleven fathoms of water." The report quoted from is a preliminary report, made by an "advisory council," and the inference is irresistible that the only reason that the advisory council assumed the necessity of, and recommended, locks, and all the evils that these entail, was on account of the supposed destructive effects which those currents were going to have upon the sides and bed of the canal. Subsequent engineers made the same assumption, and the fears so engendered have remained alive to the present day; so that it is yet impossible to speak of the Cape Cod ship canal to any merchant or other otherwise intelligent person in Massachusetts, without hearing

it answered, that owing to the necessity of locks, breakwaters, etc., the cost of such a canal would be something quite tremendous and altogether impracticable.

This leads to the consideration of what have above been referred to as the evils entailed by the plan of having locks, or a lock at either end of the canal. First, as regards an increase of cost: 1. The cost of the locks themselves, which, to accommodate, as they would have to at the present day, some 40,000 vessels per annum, would have to be built in triplicate and quadruplicate form, and, from their size, would cost large sums of money to build and to operate. 2. Since the locks at the northern end would stand upon an open seashore, on a sandy beach, they would require highly expensive works for their protection, and for the protection of vessels about to use them. It will not be necessary to enlarge upon either of these points, as they will be sufficiently appreciated by all engineers of the present day. Suffice it to say that the estimates for the two kinds of canal—the one an open cut, with jetties at the northern end to lead to deep water, the other with locks and breakwaters and jetties—compare about as 1 to 4; that is, as 2 millions of dollars to 8 millions. Secondly, comparing the two plans as to their probable income: 1. The canal is most needed in the winter, that being the most dangerous season of the year for navigation, when many coasters absolutely decline to take freights from New York, and further south, for Boston, and further north. But it is precisely then when a canal with locks would be out of service, being frozen up. On the other hand, there are good reasons, which need not now be gone into, for believing that an open cut, a "cut-off," speaking after the manner of river engineering as applied to tidal waters, would remain open all the time, especially when used by steam navigation. 2. Less detention and danger to vessels in passing through an open channel, than in passing through locks; hence greater use of the canal in the one case than in the other. 3. Less cost of haulage, or of steaming through the canal in the first case than in the second. A vessel could drift through with the tide in about three hours, and could drift either way twice every 25 hours; and naturally this drift of the current would work to the advantage of the steamer quite as much as it would to that of the sailing vessel. So that taking it altogether, it is within the mark to say that the plan with locks is simply out of question as a remunerative enterprise. Where the first would be a highly profitable

investment for private capital, the other may reasonably be shunned by even a paternal form of government; and has been shunned and has rested *in terrorem* in the minds of those interested for the past fifteen to seventeen years, ever since that unfortunate dictum—"such a fall must, we need not say, be kept under control"—and its resultant plans and estimates, and report of 1864.

To complete this sketch, and before examining the hydraulic question given in the title of this paper, it will be well to give, in concise form, the heights of tide that obtain at either end of the proposed canal, as carefully determined by observations of Henry Mitchell, the present Chief of Hydrography of the U. S. Coast Survey, in 1860-62. The table below will be all that is necessary; the heights read above (+) and below (—) the mean level of the sea, which is the same at both ends of the canal. This level is called grade 52·7 in the report.

The channel or preliminary cutting for which the velocities given in the table have been computed, for several times of the tide, has its bed about 20 ft. below the mean level of the sea at the southern end, and about 22·5 ft. below it at the northern end. It is 66 ft. wide at the bottom, and has temporary side slopes of 1·25 on 1, making the water-line from 111 to 134 ft. wide. The velocities given have been computed by Hagen's formula for *large rivers and canals*, this formula having been selected on account of its great convenience in use, and simplicity, while it remains, at the same time, a very reliable formula for large rivers and canals; but those who may prefer any other formula will readily see that the present is not one of those cases where a difference of ten and of even more per cent. in the resultant answer will be of consequence. The average skipper cares very little whether he has to tow against 3·3, or 3·6 or 3·7 knots per hour for a distance of 7·5 miles. The bottom velocities are calculated from the simple rule given by Schlichting, derived from Hagen's formulæ, and exactitude in their case, within about 10, or even 25, per cent., may also be shown to be of no serious import. These formulæ are:

$$\text{Mean Velocity} = 6 \cdot \sqrt{\frac{\text{Area}}{\text{Wetted perim.}}} \sqrt[5]{\frac{\text{Fall}}{\text{Length}}}, \quad \frac{\text{Mean Velocity}}{\text{Surface Velocity}} = 1 - 0{\cdot}0326 \sqrt{\text{Depth}};$$

and Bottom $V.$ = 3 Mean $V.$ — 2 Surface $V.$

If this sketch has served to give a rude description of the locality and canal, during the study of which the materials for the balance of

SIMULTANEOUS TIDAL OBSERVATIONS AT TERMINI OF PROPOSED CAPE COD CANAL, AUG. 14, 15, 1860, AND COMPUTED CURRENTS THROUGH CANAL.

Hour.	Height of tide in ft. at the northerly terminus.	Height of tide in ft. at the southerly terminus.	Fall in ft. on a length of about 40,000 ft.	Direction of current	REMARKS.	CURRENTS.			
						Mean Velocity. Feet per second.	Surface Vel.		At bot. and sides. Feet per sec.
							Feet per second.	Miles per hour.	
0	—1·2	—1·6	0·4	S.	Nearly highest spring tides.				
1	—3·2	—1·0	2·2	N.	Fall = 0 at 0 h. 10 m.				
2	—4·7	—0·6	4·1	N.	L. W. northern end, at 2 h. 25 m., when fall = 4·5.				
3	—4·5	—0·0	4·5	N.					
4	—3·7	+1·1	4·8	N.		3·7	4·3	2·9	2·5
5	—2·2	+1·55	3·75	N.	H. W. southern end.				
6	—0·45	+1·35	1·8	N.	Fall — 0 at 6 h. 50 m.				
7	+1·2	+0·8	0·4	S.					
8	+3·0	—0·2	3·2	S.	See Note.	[4·3]	[5·0]	[3·3]	[2·7]
9	+3·7	—1·2	4·9	S.	H. W. northern end.				
10	+2·9	—2·1	5·1	S.					
11	+1·4	—2·3	3·7	S.	L. W. southern end.				
12	0·0	—1·6	1·6	S.					
13	—1·95	—1·05	0·9	N.	Fall = 0 at 12 h. 35 m.	2·5	3·0	2·0	1·7
14	—3·75	—0·4	3·35	N.		3·3	3·8	2·6	2·2
15	—4·3	+0·4	4·7	N.	L. W. northern end.				
16	—3·3	+1·6	4·9	N.		3·7	4·3	2·9	2·5
17	—1·4	+2·4	3·8	N.	H. W. southern end at 17 h. 40 m.				
18	+0·7	+2·6	1·9	N.					
19	+2·8	+1·9	0·9	S.	Fall = 0 at 18 h. 45 m.	2·8	3·3	2·2	1·8
20	+4·5	+0·5	4·0	S.		3·7	4·4	2·9	2·4
21	+5·5	—0·8	6·3	S.	H. W. northern end.	4·1	4·8	3·2	2·6
22	+4·9	—1·7	6·6	S.	Max. fall = 6·7 at 21 h. 40 m.				
23	+3·1	—2·1	5·2	S.					
0	+1·3	—2·0	3·3	S.	L. W. southern end at 23 h. 20 m.				
1	—1·1	—1·8	0·7	S.	Fall = 0 at 1 h. 10 m.				

Mean fall in 25 hours = 3·43 ft. [irrespective of direction].

NOTE.—Calculated for a fall of 8 ft. and full canal—an extreme case.

this paper were gathered, and has served to show at least one instance where the application of such study would seem to be of decided and decisive character, it will be proper to proceed now with the consideration of the purely engineering question of the determination of the effect of running water upon the sides and the bottom of rivers and canals.

The way that has usually been followed in this particular species of investigations, hitherto, has been to find formulæ derived from series of experiments that give, from the cross-section and slope of any channel, its mean velocity; then another set that enable the surface and the bottom velocities to be arrived at; then find by experiment the effect of certain velocities on certain substances, generally in very small quantities, and resting upon smooth horizontal plank; upon which, nothing so plain, but that such and such slopes of water will carry away such and such banks and beds of the channel. It affords a healthy check, however, on these conclusions, to compare them with what we see going on around us, of this sort of action, both in rivers and in artificial channels; also not to stop the investigation with the mere *starting* of the kinds of channel surface under discussion, but to pursue the investigation a little further, and see what will take place next, and to consider the extent of such action; for, although a canal in embankment might be endangered by such operations, another, entirely in excavation, may be greatly improved by the same scouring process.

The present paper does not pretend to solve, however imperfectly, the question here presented; this could, of course, only be done in the light of extensive and well conducted experiments. Many investigators are at work in solving the problem of velocities of rivers and canals, and the distribution of velocities in any cross-section, and in that part of the general question we may, sooner or later, feel that we are standing on an unassailable foundation of knowledge, at least in the case of perfectly regular channels. In the meantime, and in default of any very decisive experiments made as yet upon the actual effect of large streams or canals upon their beds, the best immediately attainable results are those that may be derived from a compilation of such data as are recorded in engineering literature. To do this has been the essay of the following pages.

Engineering literature on the erosive or abrading power of water may be divided into three classes: 1. Experiments on the effect of

running water upon substances of various sizes and weight in artificial channels. 2. Facts to be observed in natural streams. 3. Discussions of the facts derived under the heads just cited. As some writers have done service in all three of these methods, the division will not always be followed out, but it is well enough to have it thus stated at the outset, for a better understanding of the whole subject.

Dubuat[1] [1780-84] seems to have been the first writer on the effect of currents upon the bed of the channel, who gave facts and figures, and is quoted to this day more frequently than any other experimenter. In the course of the 91 years that have elapsed since the first appearance of his book, his remarks have been translated and quoted back and forth so many times, that their original import, and weight as testimony, are hardly discernible, and it is very instructive to refer back to just what Dubuat said on the subject matter of this paper, and to consider his description of the experiments made by him.

Dubuat thought that he had found a constant relation between the mean, surface and bottom velocities of any stream, and that this was expressed by the formulæ:

$$V_s = \left[\sqrt{V_b} - 1\right]^2; \text{ and } V_m = \frac{V_s + V_b}{2},$$

using the Humphrey-Abbott notation, where V_m, V_s and V_b represent the mean, surface and bottom velocities (Sec. 66, Dubuat). These are the formulæ used by Beardmore in his Manual of Hydrology, to compute Table 3. It is high time, however, to acknowledge and recognize that these formulæ are nothing but a first approximation, and that they are deserving of no especial confidence at the present day.

Dubuat used in his experiments two rather diminutive troughs made of plank (see the plate in Vol. 2), one rectangular in section, and about 18 in. × 12 in., inside measurement; the other trapezoidal in section, about 6 in. wide at the bottom, side slopes about 1¾ on 1, and water about 8 or 10 in. deep; their length is not given. Dubuat only says he should have *liked* to have made them 500 or 600 ft. long. Besides this he made 6 experiments on a canal varying from about

[1] "Principes d'Hydraulique et de Pyrodynamique." Nouvelle edition. 3 vols. Paris, Firmin Didot, 1816. (First edition appeared in 1786.)

48 to 127 sq. ft. in section, and 4 experiments on a small river, varying from about 241 to 310 sq. ft. in section; both very shallow, only about 1 to 2 to 3 ft. deep, and 3 of these were rendered unreliable by untoward circumstances, as detailed by Dubuat himself. Nevertheless, these spoiled experiments, and the others, are to this day occasionally used by the constructor of hydraulic formulæ. All the experiments were conducted in a tolerably crude manner, looking at them in the light of the much more carefully and exactly conducted ones of later times, the velocities being generally measured by little wooden and other floats (gooseberries for measuring bottom velocities), levels taken by measuring down from pegs, etc., so that, taken altogether, if the whole of Dubuat's experiments were dropped out of all future consideration, it would no longer be a serious loss to science; indeed, to consider them, and give them the same weight with many more perfectly derived ones of later days, in the study or derivation of formulæ, they cannot but be looked upon as decidedly unscientific, and resembling, in some degree, that celebrated "survey" of the American humorist, John Phœnix, Esq., who averaged the distance as given between two places, by a peculiar sort of triangulation, of astronomical observation, and of direct chaining, and by casual estimate of a bystander, as the best result attainable.[1]

The same little troughs mentioned above, served for the experiments on the "abrading and transporting power of water," the *rolling* along of gooseberries giving the bottom velocities. These results of Dubuat's experiments are best given in the table of Vol. 2, Sec. 399, though they are also stated in words, somewhat incompletely translated, as usually quoted, in Sec. 71 of Vol. 1.

[To be continued.]

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[1] To discuss, as part of the general question, the subject of what is called the "scale of velocities" in currents, and the dependence of the mean or surface velocity upon cross-section and slope, and to bring such discussion to date, would extend this paper to the size of a comprehensive treatise on hydraulics. The writer cannot venture upon this field of labor at this time, and, in place thereof, may leave, without argument, to each engineer the use of such well founded formulæ as seem best to him. That there is no one formula, or no one set of formulæ, that commands universal respect and confidence among engineers, is much to be regretted. Just at present, this matter is in a peculiarly deplorable state, from over-zeal of writers to evolve something new, in the first place, and absolutely exhaustive, in the second, and without due regard to a proper study of the subject, or to the quality of the data which they recklessly throw pell-mell into their formula-producing chaldron.

EXPERIMENTS MADE TO DETERMINE THE INFLUENCE OF TEMPERATURE ON THE DISCHARGE OF WATER FROM AN ORIFICE IN THE HEMISPHERICAL BOTTOM OF AN OPEN TOPPED CYLINDRICAL VESSEL.

By Chief Engineer ISHERWOOD, U. S. Navy.

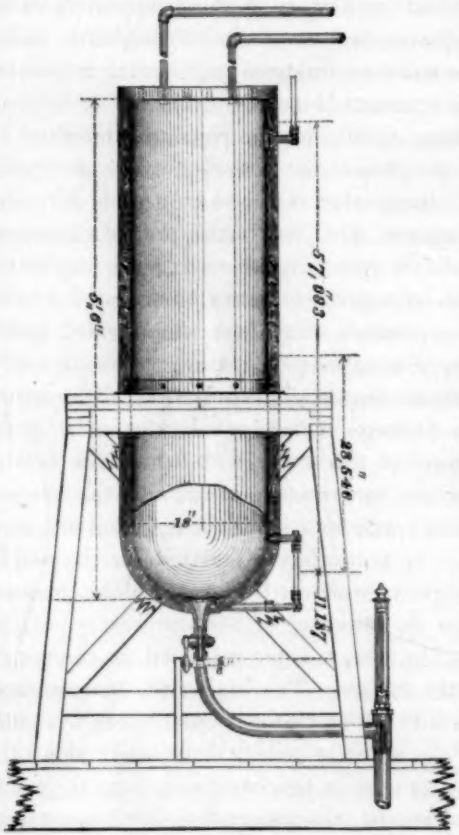
That the mobility of water is greatly influenced by its temperature, is a fact obvious on inspection to any discerning eye; but the writer is not aware that any experiments, except those recorded in this paper, have ever been made to determine the comparative value of that influence for the different degrees of the thermometric scale. The importance of this determination in steam engineering is greater than may at first sight be apparent, for not only is the leakage of water from boilers affected by it, but also the resistance of water to motion in pipes, and to the progress of the immersed solids of vessels.

The first is of practical consequence in the testing of boilers, the second in all pumping operations, and the last in the propulsion of vessels. It will be seen from the results of these experiments that a boiler which may be tight under a given pressure when tested by the pumps with water of one temperature, may leak when tested under the same pressure with water of a higher temperature; so that a really complete test of boiler tightness requires not only that the pressure shall be equal to the steam-pressure which is to be carried in practice, but that the temperature of the water with which the test is made shall be the same as the temperature normal to this steam-pressure. Again, in pumping operations, it will be seen that the duty of a pumping-engine cannot be accurately calculated for the weight of water raised and the height to which it is elevated alone, because it must have a correction for the influence of the temperature of the water, as the higher that is, the less, in some ratio, will be the resistance the water opposes to the engine. The higher the temperature, the greater is the freedom with which the molecules glide over and around each other, causing the water to deflect more easily along the sinuosities of the pipes, and to receive less resistance from their surfaces. In the propulsion of vessels, the water of higher temperature opposes, for the same reasons, less resistance to their passage than water of lower temperature, even allowing for their greater draught in the warmer water due to its less density.

In the various determinations which have heretofore been made of the ratio of the actual to the theoretical discharge of water through orifices, the temperature of the water should have been noted, as the actual discharges, *ceteris paribus*, are affected by it, while the theoretical discharge remains constant at all temperatures. The experimental ratios are true for only the experimental temperatures, and need reduction to a standard temperature.

Description of the Apparatus.

Fig. 1.

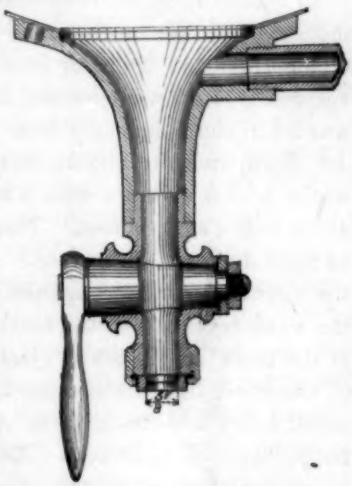


The apparatus, Fig. 1, consisted of a vertical cylinder, 18 inches in external diameter, with an open top and a hemispherical bottom, the whole being 5 ft. 6 in. in height, and made of copper as thin as consistent with rigidity of form. The lower part of the bottom had an aperture of 4 inches diameter, to which was bolted a vertical brass bell-mouth of 4 inches internal diameter at top, and $1\frac{1}{16}$ in. internal diameter at bottom, the sides being formed of converging curves. The bell-mouth was $4\frac{1}{8}$ inches in internal height, and its axis was in the same vertical as that of the cylinder; near its top was a horizontal cylindrical nozzle, into which was screwed a small water-pipe communicating with the lower glass water-gauge. Into the bottom of the bell-mouth an ordinary stop-cock was screwed, having a water-way of 0·77 inch

diameter, to which was adjusted a washer or disc of brass (see Fig. 2), one-fourth of an inch thick, perforated with a hole of five-eighths of an inch least diameter, the sides of this hole were rounded on a semi-circle, and its axis was in the same straight line with the vertical axis of the stop-cock and bell-mouth.

At 1 inch below the washer was placed a pipe of $1\frac{1}{4}$ inches inner diameter, to receive the water discharged, the column of which was therefore in open view. This pipe was curved laterally, and connected to a vertical drain-pipe of $1\frac{1}{2}$ inches inner diameter, situated 6 inches from the axis of the cylinder. In the vertical pipe was placed a large thermometer with a long bulb, protected by a perforated casing of brass. The bulb was opposite and below the junction of the two pipes, so that the water discharged flowed freely over it. The apparatus was supported upon a stout wooden framing, by means of a brass flange, riveted to the cylinder. Attached to the side of the cylinder were two glass water-gauges, having their vertical axes in the same straight line, one near the top, and the other near the bottom.

FIG. 2.



The open top of the cylinder had a wooden cover, part of which was screwed fast to the cylinder, and had passing through it two pipes, one leading to the water space of a steam boiler in use, and the other to the water of the Croton aqueduct. Both pipes were fitted with suitable stop-valves, and by their means the cylinder could be filled with water of any temperature between 32° and 212° Fahr. The remaining part of the cover was removable, and was perforated with a number of small holes, to allow the escape of the steam when the valve in the hot-water pipe—or pipe connecting with the boiler—was open.

The entire cylinder and its hemispherical bottom were closely covered with felt $1\frac{1}{2}$ inches in thickness.

The apparatus was erected in the engine-room of the boiler-shop of the "Novelty Iron Works" in the city of New York, and all its

appendages being complete and found perfectly tight, the cylinder was nearly filled with water, and a permanent mark made at its level on the upper glass water-gauge. Eight and one-half cubic feet of water were then measured out of the vessel, drawing it off into a box of exactly one cubic foot capacity, made especially for the purpose; this brought the water-level to a convenient point for observation in the lower glass water-gauge, which point was permanently marked on the lower gauge in a similar manner to the upper one.

Manner of making the Experiments.

In commencing an experiment, the cylinder was filled to a few inches above the mark on the upper glass water-gauge, with water, either from the boiler or from the Croton aqueduct, or from both, according to the temperature desired. In the latter case, the water was let in simultaneously from both pipes, so as to mix as the cylinder filled, and the mixing was made more thorough by stirring the water in the cylinder with a board having a surface on one side of about half a square foot. This board was fitted with a long handle at right angles to its surface. As soon as the water became quiescent the discharge-cock was opened, and the exact times were noted when the water-level was at the mark on the upper glass water-gauge, and at the mark on the lower glass water-gauge. During the discharge of the water between the marks on the gauges, the thermometer was noted every minute, and the mean of the observations taken for the temperature of the water. As the cylinder was filled about 2 inches above the upper mark, the water had sufficient time to acquire its velocity in descending to that mark, independently of the time consumed in opening the discharge-cock. It will be observed that the area of the water-way through the plug of this cock was nearly one and a half times the area of the discharge-orifice through the washer; therefore, no small difference in the opening of the cock could influence the freedom of the discharge; but, to prevent any question, a stop was properly fixed, so that the handle of the cock always opened against it. The discharge orifice was not changed during the experiments; and the column of water issuing from it being in full view, any accidental obstruction, had any occurred, would have been immediately detected. The water entered the lateral pipe in the form of a smooth cylinder, except at the highest temperatures, and losing there the

greater part of its velocity, flowed around the bulb of the thermometer, and passed into the drain-pipe. During a portion of the experiments the time was noted by a stop-watch, but it was found that by holding a common watch in such manner as to bring the second hand close to the marks on the glass water-gauges, the eye could note the time fully as quickly and as accurately as the thumb could press the spring of the stop-watch. When filling the cylinder with a mixture of hot and cold water, both were allowed to run in at the same time, and the equality of the temperature of the mass was assured. By carefully observing this simple process, the temperature, when low, of the discharging water, would not vary over a degree, and when high, not over four or five degrees between extremes. The temperature of the water from the Croton aqueduct was, for most of the time, about 37 degrees Fahrenheit, and for experiments with lower temperatures it was reduced by ice, in which cases the water was thoroughly stirred and the unmelted lumps of ice skimmed off before opening the discharge-cock. The water used in the boiler was also from the Croton aqueduct.

The experiments were two hundred and forty-six in number. They occupied many days, and were about equally distributed between the temperatures of 32 degrees and 212 degrees Fahrenheit. From their corrected results the following table was formed by laying off by scale, on a straight line, the observed temperatures as abscissæ, and erecting at right angles to this line, as ordinates, the corresponding times by scale of discharge, drawing as nearly as possible, through the free ends of the latter, a fair curve, leaving as many points on one side of it as on the other. From the graphic curve thus obtained, the times in seconds of the discharges of the eight and a half cubic feet of water of every degree of temperature on Fahrenheit's scale, from 32° to 212°, were accurately measured off by scale. These times, for every fourth degree, will be found in the second column of the table, and are, of course, for *equal volumes*. In the fourth column of the table will be found the times in seconds of the discharges of *equal weights* of water of the temperatures in the first column, taking the weight to be that due to the eight and a half cubic feet at the temperature of 39° Fahrenheit; these quantities are derived from those in the second column by modifying the latter according to Kopp's determination of the relative volumes of an equal weight of water at different temperatures.

TABLE

EXHIBITING THE RESULTS OF EXPERIMENTS MADE FOR THE PURPOSE OF DETERMINING THE EFFECT OF TEMPERATURE ON THE DISCHARGE OF WATER FROM AN ORIFICE IN THE HEMISPHERICAL BOTTOM OF AN OPEN TOPPED CYLINDRICAL VESSEL.

Temperature in degrees Fahrenheit.	Time of Discharge in Seconds.				Relative Velocities of Discharge.	
	For equal volumes.		For equal weights.			
	Absolute.	Relative.	Absolute.	Relative.	For equal volumes.	For equal weights.
32	848·25	1·0000	848·3425	1·0000	1·0000	1·0000
36	847·20	0·9988	847·2169	0·9987	1·0012	1·0013
40	845·95	0·9973	845·9517	0·9972	1·0027	1·0028
44	844·80	0·9959	844.8448	0·9959	1·0041	1·0041
48	843·55	0·9944	843·6942	0·9945	1·0056	1·0055
52	842·15	0·9928	842·4473	0·9930	1·0072	1·0070
56	840·85	0·9913	841·3520	0·9917	1·0087	1·0084
60	839·40	0·9896	840·1563	0·9903	1·0105	1·0097
64	837·85	0·9877	838·9074	0·9889	1·0124	1·0112
68	836·30	0·9859	837·7050	0·9875	1·0143	1·0127
72	834·70	0·9840	836·4954	0·9860	1·0163	1·0143
76	833·10	0·9821	835·3285	0·9846	1·0182	1·0158
80	831·50	0·9802	834·2015	0·9833	1·0202	1·0170
84	829·70	0·9781	832·9126	0·9818	1·0224	1·0186
88	827·95	0·9761	831·7105	0·9804	1·0245	1·0200
92	826·20	0·9740	830·5441	0·9790	1·0267	1·0213
96	824·35	0·9718	829·3118	0·9775	1·0290	1·0230
100	822·50	0·9696	828·1111	0·9761	1·0313	1·0245
104	820·65	0·9675	826·9427	0·9748	1·0336	1·0258
108	818·75	0·9652	825·7536	0·9734	1·0360	1·0273
112	816·85	0·9630	824·5929	0·9720	1·0384	1·0288
116	814·85	0·9606	823·3587	0·9705	1·0410	1·0304
120	812·90	0·9583	822·2012	0·9691	1·0435	1·0319
124	810·85	0·9559	820·9678	0·9677	1·0461	1·0330
128	808·75	0·9534	819·7086	0·9662	1·0489	1·0350
132	806·60	0·9509	818·4207	0·9646	1·0516	1·0367
136	804·40	0·9483	817·1031	0·9631	1·0545	1·0383
140	802·20	0·9457	815·8069	0·9616	1·0577	1·0399
144	799·90	0·9430	814·4286	0·9600	1·0604	1·0416
148	797·70	0·9404	813·1706	0·9585	1·0633	1·0434
152	795·30	0·9376	811·7269	0·9568	1·0665	1·0451
156	792·90	0·9347	810·3002	0·9551	1·0698	1·0469
160	790·40	0·9318	808·7863	0·9534	1·0732	1·0489
164	787·80	0·9287	807·1832	0·9515	1·0767	1·0509
168	785·10	0·9255	805·4953	0·9495	1·0804	1·0532
172	782·30	0·9222	803·7147	0·9474	1·0843	1·0555
176	779·60	0·9191	802·0494	0·9454	1·0880	1·0577
180	776·70	0·9156	800·1990	0·9432	1·0922	1·0604
184	773·70	0·9121	798·2356	0·9409	1·0963	1·0628
188	770·80	0·9087	796·3944	0·9388	1·1005	1·0652
192	767·75	0·9051	794·4070	0·9365	1·1048	1·0678
196	764·50	0·9012	792·2200	0·9338	1·1096	1·0708
200	761·30	0·8975	790·0916	0·9313	1·1141	1·0736
204	757·90	0·8935	787·7605	0·9286	1·1192	1·0769
208	754·50	0·8895	785·4345	0·9258	1·1241	1·0801
212	751·10	0·8855	783·1184	0·9231	1·1293	1·0833

The experimental results were corrected for the varying area of the discharge aperture according to the temperature of the water passing through it; the mean linear dilatation of the brass for each degree Fahrenheit, between the temperatures of 32° and 212° Fahrenheit, being taken at 0·00001052 of the length at 32°.

These experiments were made in 1863, and the writer's duties at that time, as Chief of the Bureau of Steam Engineering in the Navy Department, preventing him from giving them his personal attention, they were very carefully and skilfully conducted for him, after the apparatus was constructed, and the manner of experimenting arranged, by Mr. Charles E. Emery, then an engineer in the United States Navy, from whose tabular records or logs of the experiments the writer, after making the corrections above stated, protracted the graphic curve representing their results, and from it constructed the foregoing table. The headings of the columns in this table are so descriptive of their contents as to need no further elucidation.

A remarkable result of these experiments is that the relative velocities of discharge for equal weights of water at different temperatures, are in the ratio of the squares of the relative volumes of equal weights of water at the same temperatures.

FALL OF A HYDRAULIC ELEVATOR AT THE GRAND HOTEL IN PARIS, FRANCE.

By W. Barnet Le Van.

On Sunday morning, February 24th, 1878, the car of the hydraulic elevator of the Grand Hotel being at the second floor, two passengers and the conductor entered it, for the purpose of descending to the first floor.

The conductor started the car to lower, but, instead of descending, the car began to ascend with an alarming rapidity. The casting which connected the piston to the bottom of the car had parted. The car, in ascending to the second floor, was lifted by the pressure of the water under the piston, as usual, but on the opening of the

valve, to let the water flow out from beneath the piston, the reaction of the heavy piston commencing to fall, with the water and the counter-weights acting to pull the car upwards, broke the casting that connected the car with the piston.

The piston immediately commenced to descend in its cylinder, while the counter-weights—now greatly exceeding the weight of the car and its occupants—began to run down and pull the car up at a rapid rate, bringing the top of the car in violent contact with the cross-beams overhead for supporting the pulleys carrying the chains of the counter-weights. The shock was so great that the chains parted, and the car descended by the force of gravity, rapidly increasing from second to second, until it reached the basement, a distance of twenty metres, or sixty-five feet (exactly 65·618 ft.). The weights also fell, and the concussion produced caused a loud report.

On opening the car, the three occupants were found dead. The bodies of the unfortunate persons presented no trace of external or internal injury, except a few drops of blood from the ear of one and the mouth of the others, showing that congestion of the brain had taken place.

The accident was due to a honey-combed casting, which did not show until after the accident. Every precaution had been taken by the management of the hotel to avoid accidents, so far as it was possible to foresee them.

The elevator had only been in use eighteen months, having replaced a former one.

Description of the Elevator.

The lift, or elevator, consisted of a cast-iron cylinder placed in a well the depth of the required lift, in this case it being about seventy feet. In this cylinder was placed a ram or piston, accurately turned. On the top of the cylinder was placed a stuffing-box, so as to securely pack the ram, and prevent leakage of the water used to operate it. On top of and connected to the ram by a casting, was placed the car for passengers. On the side of the cylinder, below the stuffing-box, was an inlet, to which was attached a three-way valve, which was also connected to a cistern placed on top of the building. This valve was operated by a lever, the end of which was connected to a

rod passing through the car to the top of the elevator, thus enabling the conductor to control the movements of the car.

When the lever was in a horizontal position, all communications to the cylinder were closed. On raising the lever the water flowed into the cylinder, causing the ram to ascend at a speed due to the head of water in the cistern at the top of the house; and by lowering the lever from a horizontal position, the connection from the cistern was shut off, and the cylinder was put in communication with the waste-pipe, which allowed the ram to descend. The weight of the ram and car was nearly balanced by two weights, connected to the car by chains which passed over two pulleys placed on the top of the lift. The water in the cistern had only to lift the difference between the weight of the car and piston and that of the counter-weights and load the car was to carry.

The point of fracture was immediately under the car, being the cast-iron connection between the car and ram; and it was found, on examination after the accident, to be due to the casting being of an imperfect porous structure—what is technically termed honey-combed.

From all I can learn, the elevator was not provided with safety catches, such as are used with elevators in this country, and the use of chains to suspend the counter-weights is questionable, as they do not run as smoothly as wire cords, and are more likely to break.

According to the laws of falling bodies, the car reached the basement from the top of the hotel in two seconds:

$$T = \sqrt{\frac{2H}{g}}$$

T = time of fall in seconds.
H = height, in feet, fallen through in the time T.
g = acceleratrix = 32·17.

$$T = \sqrt{\frac{65{\cdot}6 \times 2}{32{\cdot}17}} = 2{\cdot}02 \text{ seconds.}$$

Allowing one second for the time the car took to reach the top of the building, the whole time of the accident did not exceed three seconds.

EXAMINATION OF THE PHONOGRAPH RECORD UNDER THE MICROSCOPE.[1]

By Persifor Frazer, Jr., A. M.

At a meeting of the Philosophical Society, held April 5th, 1878, I described the results of some examinations of the tin foil which had been indented by the stylus, or needle point, of the phonograph.

My object was to ascertain the shapes of the indentations made by different known sounds. For this purpose, Dr. Plush, the superintendent of the Philadelphia Local Telegraph Co, kindly offered his assistance. The vowels and diphthongs were spoken into the mouthpiece of the apparatus with small panels in the order seen on the diagram.

These sounds were repeated thrice on each of three foils. They were then mounted on glass plates, separated, and labeled. Finally, at the suggestion of Mr. Knight, they were cut out and mounted on another piece of glass vertically, instead of horizontally, in order that a number of the dents produced by any given sound might be on the screen at once. I am much indebted to Mr. Holman for his kindness in adapting the apparatus, which he himself will explain a little later to the purpose of showing these phonographic records.

Lissajous, Leon Scott and König have provided the means of transforming sounds into form, in various ways, viz.: By bright points on the ends of steel bars of different thicknesses; by vibrating membranes at the extremity of a "phonautograph," and by flames reflected in a rotating mirror. It was natural to conclude that the same vibrations, imparted to a steel point by means of a metal diaphragm, would leave an equally characteristic trace.

It was intended to take a solid cast of these depressions in Canada balsam, or some other transparent substance, and then reproduce, in the mind's eye, the path of the stylus point. There has not been time for this.

The same voice (that of Dr. Plush), speaking the following vowels and diphthongs as nearly as possible at the same distance from the mouthpiece, was relied upon for the matrices.

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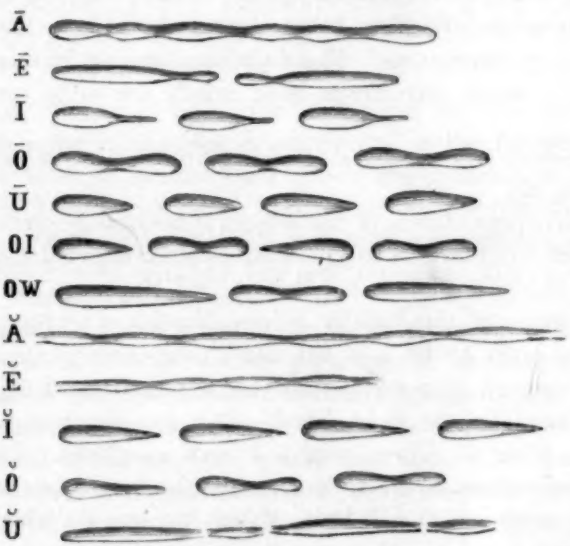
[1] Presented at the meeting of the Franklin Institute, April 17th, 1878.

The first records tried, to ascertain whether the pronunciation was perfect, were afterwards thrown away, and the records which were studied were not in any way injured by a second passage of the point of the stylus.

By following along the nearly vertical line of impressions, which are at the same time in focus, it will be observed that this line consists of one long followed by two shorts (or two shorts followed by one long), the indentations bearing a general resemblance to each other and to seeds. This is long A, or "Ah." A glance at short ă



[Note.—In the wood-cut, the forms made by the excursions of the stylus for the short letters are wider than they should be.]

(as in "bat"), will show the same thing, but the seed-shaped hollows are narrower, and there are no abrupt terminations of the hollows by intervening parts of the foil which have not been touched by the needle-point.

Ē (or ay), on the screen, looked like the magnets of two Bell telephones, with the small ends turned towards each other. In the diagram they look like two Indian clubs with the handles together. The same general resemblance is observed in E short, except that, as in ă short, the volume of sound being less, the intensity was less, or (what is the measure of intensity) the path of the needle-point was

shorter, and it seldom entirely cleared the foil; the consequence being a continuous groove of irregular, but normally irregular, width.

Dr. Nolan, in faithfully transcribing the general appearance, to the eye, of these curves, was, of course, not able, in the limited time given him, to preserve the absolute thicknesses and lengths. These will be added in the memoir in the Proceedings of A. P. S., in the form of micrometric measurements to the ·001 mm.

Ĭ and Ī are much alike in general form, as also are Ŏ and Ō, the coupling of the pairs of the latter being the most striking feature. Ŭ and Ū, in the drawing, best show the difference in shape produced by less intensities; the short being drawn out, and more acicular.

OI is very interesting. The diphthong consists of ŎĬ, and the very moulds which characterize their sounds are to be observed in the cut.

OW presents a composite character, but its derivation has not yet been made out.

The above presentation of the subject is necessarily crude and imperfect, but will illustrate the possibilities of an exhaustive investigation. It should be added, that Prof. Alfred Mayer has published, in the last number of the *Popular Science Monthly*, a representation of the curves made by the ă in bat, and a comparison of them, and of a section through their middle, with the curves of the König flames, when agitated by the same sound. This was not brought to my notice till after the above work had been completed. There is a general resemblance between the forms of the excavations thus independently produced, though Prof. Mayer has one dot which I have not observed.

Telephonic Transformations.—M. A. Demoget, of Nantes, estimates that only about $\frac{1}{1800}$ of the sound which is communicated to the telephone is transmitted to the receiver. He considers that the muscular effort of the speaker is transformed: 1, into vibrations of the air; 2, into metallic vibrations; 3, into magnetic waves; 4, into electric induction; 5, into magnetic induction; 6, into metallic vibrations; 7, into vibrations of the air; 8, into vibrations of the auditory apparatus. If we suppose the loss of useful effect at each transformation to be equal, the loss would be comprised between $\frac{2}{3}$ and $\frac{1}{2}$. This represents, very nearly, the experimental efficiency of pumps.—*Les Mondes.* C.

Action of Oxygen upon Anatomic Elements.—Bert has been studying the toxic action of oxygen under high tension. He finds, by the indirect method of air confined under pressure, that the injurious influence of oxygen upon air-breathing vertebrates begins when its tension corresponds to a pressure of five or six atmospheres. The analysis of the gases contained in arterial blood shows that under this tension the coloring matter of the globules is completely saturated with oxygen, and that gas begins to be dissolved in the sanguine plasma. If the compression is long continued, the solution of oxygen becomes diffused through the tissues, and the organic oxidations are diminished, leading to an immediate reduction of the temperature of the body.—*Comptes Rendus.* C.

Pasteur Prize.—Dumas has announced the foundation of a special prize by an anonymous contributor, in the following terms: "The works of M. Pasteur have opened new processes to medicine. A prize of 6000 francs will be decreed, in 1880, by the Academy of Sciences, to the person who shall have made the most useful application of these works to the healing art."—*Comptes Rendus.* C.

Microscopic Mineralogy.—A. Michel Lévy has contributed to the *Annales des Mines* a valuable paper upon the use of the polarizing microscope, for the determination of mineral species by small sections. The investigations of Rosenbusch, Fouqué, and Descloiseux, although all embraced within the last decade, have already become classical. Lévy tabulates their conclusions, and gives a complete mathematical analysis of the angles of extinction presented by the sections of a zone, together with a practical application to the study of the principal monoclinic minerals, and of some triclinic feldspars. C.

High Furnaces.—M. L. Greever divides smelting furnaces into two classes, which he calls *trapu* (squat), and *elancé* (long). In the trapu, the height does not exceed three times the length; in the elancé, the ratio is four or more; and he admits an intermediate class, the *ordinaire*, in which the ratio is between three and four, and generally about 3·5. He compares the productions of various furnaces in England, Styria, Corinthia, America, Sweden, Germany, and France, drawing conclusions unfavorable to the elancés, which have increased so largely within the last quarter of a century.—*Annales des Mines.* C.

Influence of Electricity on Evaporation.—Mascart arranged a series of small evaporating basins under conductors, which were kept in a constant electric state by a Holtz machine, moved by water-power, and placed under a glass cage, in which the air was dried by vessels containing sulphuric acid. He found that the evaporation was constantly increased under the electrized gratings, whether the electricity was positive or negative, evaporation being sometimes doubled."—*Comptes Rendus.* C.

Cementation of Nickel.—Boussingault has experimented to find whether the carburation of nickel would affect it like iron, and, if so, whether its combination with steel would render it less oxidizable. Although he was able to carbonize the nickel as highly as steel, he did not find any increase of elasticity, hardness, or resistance to tension; he was unable to temper it; and the alloy with iron easily rusted, unless the nickel was in very large proportion. Damour found, in the meteoric iron of Santa Caterina, 34 per cent. of nickel. Boussingault exposed a piece of it under water, for more than a month, without finding the least rust. He then made a very homogeneous alloy, by melting 63 parts of steel with 37 parts of nickel, which was malleable and resisted the action of water as well as the Santa Caterina iron.—*Comptes Rendus.* C.

Proposed Prize.—The London Society of Arts offers a prize of $500, and the medal of the society, for the best memoir on the jeweler's art in the present and past times, with practical suggestions for its future development. The memoir should specify the principal works which have been produced in different countries, and the prize will not be awarded to any memoir of inferior merit. The communication should be addressed to the Secretary of the Society of Arts, John St., Adelphi, London.—*Les Mondes.* C.

Sewage of Reims.—A commission was lately appointed to advise with regard to the best disposition of the sewage water of the city of Reims. On account of immediate urgency they recommended the temporary employment of chemical clarifiers, accompanied by experiments upon the agricultural application, of such portions as were most favorably situated for the purpose. They believed that all the sewage might ultimately be applied with advantage to the soil, without requiring any previous chemical reaction.—*Ann. des Ponts et Chaussées.* C.

Delicate Manometers.—The want of manometers of great precision, capable of measuring the smallest difference of gaseous pressure, has long been felt. Peclet was the first experimenter who succeeded in approximately satisfying the want. Palamede Guzzi describes an improved instrument in *Il Politecnico* (v. 25, pp. 689–702), by which he is able to measure differences of pressure equivalent to $\frac{1}{500}$ of a millimetre of water. C.

Resistance of Iron to Repeated Blows.—Giambattista Biadego publishes a note upon the determination of the strains which iron can sustain, with special reference to Wöhler's experiments upon the effects of repeated blows. He recounts the experiments of Fairbairn (1849–61), Wöhler (1859–70), and Spangenberg; the analytical discussions of Gerber (1872), Launhardt (1873), Weyrauch (1877), and Winkler (1877); and some deductions of his own; giving a preference to the formulæ of Launhardt, as improved by Weyrauch.—*Il Politecnico.* C.

Wood Injection.—The value of creosote as a wood preserver is generally recognized, but the direct injection requires great quantities of heavy oil, and a desiccation of the injected pores. The high boiling-point of creosote (300°) does not permit its employment in vapor. John Blythe formed the idea of saturating a jet of steam with creosote in minute division, forming, so to speak, a gaseous emulsion. The apparatus comprises a high-pressure steam-boiler; another boiler containing creosote, in which the steam is saturated; a vat, filled with creosote, to be pumped into the boiler; sheet-iron cylinders, for the pieces which are to be injected; and a system of tubing connecting the several parts. In this way Mr. Blythe completely fills the heart of oak, pine, or red beech; he uses 2 to 3 kilos. of creosote for a cross-tie, and 2 kilos. of brown phenic acid per cubic metre of saturated wood or cross-ties. The cost of preparing a cross-tie, measuring 0·085 m., is from 0·60 f. to 0·70 f. The apparatus can prepare 500 ties per day; the wood comes out softened, so that it can readily be bent or shaped, but it rapidly hardens; at first it shrinks, but after a few weeks it becomes seasoned and resists the influences of moisture; finally, the fibres are greatly strengthened.—*Ann. des Ponts et Chaussées.* C.

Compound Locomotives.—M. Mallet has presented a communication to the French Academy, on the application of the compound system to locomotives on the railroad from Bayonne to Biarritz. The engine has two cranks, at right angles, driven by two cylinders, one on each side. They have a range of 0·45 m., the diameter of one being 0·24 m., the other 0·40 m. Under ordinary circumstances, the steam from the boiler passes first into the small cylinder, then into the large, where it acts expansively, and finally escapes into the chimney. But on starting, and whenever the engine is required to surmount an increased resistance, the steam may be admitted directly into the large cylinder, and the locomotive acts as an ordinary two-cylinder engine. The plan has been adopted in three engines, with four coupled wheels of 1·20 m. diameter; the boiler has 45 square metres of heating surface, and acts with an effective pressure of 10 kg. per square centimetre. They are employed in local traffic, on grades of 0·015. Their action is unexceptionable, their steadiness leaving nothing to desire, even at a speed of 40 km. per hour, and the management being no more difficult than in ordinary engines. The draught, notwithstanding the reduction of the steam-jets to one-half, is ample, so that the boiler, in spite of its small dimensions, supplies the wants of the engine abundantly. As for the consumption of fuel, the gross cost per kilometre is 4 kg. of Cardiff coal for trains weighing 50, 60 or even 70 tons. The foregoing facts are derived from a service of 40,000 km., performed since the system was adopted. They have, therefore, an important practical value.—*Ann. des Ponts et Chaussées.* C.

New Determination of the Mechanical Equivalent of Heat.—At the meeting of the Royal Society, held Jan. 24th, 1878, J. P. Joule, F. R. S., etc., read a paper, in which he gives an account of the experiments he has recently made, with a view to increase the accuracy of the results given in his former paper, published in the *Philosophical Transactions* for 1850. The result he has now arrived at, from the thermal effects of the friction of water, is, that taking the unit of heat as that which can raise a pound of water, weighed in vacuo from 60° to 61° of the mercurial thermometer; its mechanical equivalent reduced to the sea level, at the latitude of Greenwich, is 772·55 foot-pounds.—*Proceedings of the Royal Society.* *

The Byrne Cautery Battery.—At the meeting of the Institute in March, Dr. F. Cleland presented and described this battery, which is intended to provide the medical profession with a portable battery, capable of producing a considerable amount of heat, as is required in cauterizing operations. Its peculiarity is in the construction of the negative plate, which consists of a sheet of platinum, to the back of which is soldered a plate of copper, which in turn is covered with a sheet of lead. The copper extends above the platinum, and is firmly attached to the yoke. The lead covering is merely to protect the copper plate from the action of the exciting liquid.

Two of these compound plates are arranged to face the zinc plate in each cell, and four cells are placed in a case $8\frac{1}{2} \times 7\frac{1}{4} \times 4\frac{1}{8}$ inches, exposing in all less than 80 square inches each of platinum and zinc surfaces to the action of the exciting liquid, and giving, it is claimed, an electro-motive force of 7·96 volts, with an internal resistance of less than ·06 of an ohm.

Small tubes extend down into the liquid, through which air is forced by a small india-rubber ball pump, held in the hand, and by agitating the liquid greatly increases the intensity of the current, and thus enabling the operator to control the heating effect without the aid of an assistant.

This battery will raise to a white heat 20 inches of No. 16 platinum wire, and will maintain it for 30 to 40 minutes. *

Book Notices.

MATTER AND MOTION.—By J. Clerk Maxwell. Van Nostrand's Science Series, No. 36. Price, 50 cents.

The name of the author is a sufficient guarantee for the excellence of any work which he undertakes. Some apprehension might naturally be felt that a writer who is so familiar with profound mathematical analysis, would find it difficult to treat elementary physics with such simplicity as is desirable. A brief perusal of pages 14 to 21 will show how groundless such an apprehension is, in the present instance. The fundamental principles of quaternions, including the addition and subtraction of vectors, are interpreted in a way which is perfectly lucid in itself, and which gives, even to minds of ordinary mathematical ability, satisfactory notions of some of the advantages of modern mathematical methods. The discussions on the ideas of space and time, on the error which "runs through every part of Descartes' great work, and . . . forms one of the ultimate foundations of

the system of Spinoza," and on the comparative practical importance of absolute and relative knowledge, and the "statement of the general maxim of physical science" [pp. 23-32], are fine illustrations of the advantage of combining accurate mathematical study with abstruse metaphysical speculation. The subjects of motion, force, centre of mass, work and energy, pendulum, and universal gravitation, are all well treated, the two closing chapters being especially admirable.

Some exception may very properly be taken to the definition of centrifugal force on page 171: "This is the force which must act on the body, m, in order to keep it in the circle of radius, v, in which it is moving with velocity, V. The direction of this force is towards the centre of the circle."

The following statement also seems to require some qualification: "But it is extremely doubtful whether the medium of light and electricity is a gravitating substance, though it is certainly material and has mass." Maxwell's connection of electrostatic and electromagnetic force by means of the velocity of light, and the more recent identification of the same velocity with limiting velocities in solar centripetal and centrifugal force, and in various forms of chemical activity, render it extremely probable, although by no means certain, that the luminiferous ether is material; but the instantaneous action, which is required by gravity and telephony, is wholly irreconcilable with any theory of mere material action.

We regret to notice some typographical errors, which indicate either ignorance or inexcusable carelessness in the proof-reading: *E. g.*, A_1B_2, for A_1B_1, p. 35; *oo* for *ao*, p. 35; instance, for instants, p. 40; 980′, for 980, p. 42; O, for 0, p. 115; meter, for metre, *passim*.

C.

REPORTS AND AWARDS OF THE INTERNATIONAL EXHIBITION, 1876.—Edited by Francis A. Walker, Chief of the Bureau of Awards. J. B. Lippincott & Co., 1877. Group II, Pottery, Porcelain, Brick Clays, Cements and their Materials, etc.

The general report of the Judges of this group covers 250 pages, exclusive of the report on awards. It commences with a short historical sketch of the progress of the potter's art within the last one hundred years, and then gives a general review of the display of pottery and porcelain at the Centennial as a whole.

The number of exhibits in the group, including glassware, is 592, of which 199 are from the United States; some of the exhibits from foreign countries are remarkable for the number of pieces, and the size and value of individual specimens.

Europe was not represented at her best, many of the leading English and Continental houses being represented indifferently, or not at all.

Oriental porcelain was represented by collections of great interest, extent and variety; the Japanese constituting the most important contribution to the Ceramic Department.

The contribution of American pottery is noticed somewhat more in detail, because of its importance to the country as a manufacturing industry, and also because of its sudden and remarkable development within a comparatively few years. The history of this growth forms a preface to the detailed report on the American exhibits.

Of these detailed reports there is one for each nationality, all of which are written with evident impartiality and good judgment.

Among the special reports, that by Prof. Henry Wurtz, on the chemistry and composition of the porcelains and porcelain rock of Japan, is of especial value.

The report on cements and artificial stone, or bricks, brick machinery, and pavements, etc., by Gen. Q. A. Gilmore, covers the ground remarkably well, and, from the high reputation of the writer, will be received as authority on these subjects.

The experiments on the tensile and crushing strength of cements, the results of which are given on page 167, are worthy of notice.

The reports on awards, commencing with page 251, are uninteresting, covering, as they do, only the reasons for which medals are recommended.

Reports on quite a number of other groups have been received and will be noticed hereafter.

Meanwhile we would call attention to what seems to be an error in design and arrangement. The report on each group is contained in a separate pamphlet, with independent paging, evidently not intended to be bound into volumes; there are no indexes to the separate pamphlets, and this independent paging makes it impossible to prepare one for the whole set, and therefore their value for purposes of reference is greatly reduced.

The mechanical execution is good, being printed on excellent tinted paper, in large, clear type.

PROCEEDINGS OF SOCIETIES.

Engineers' Club of Philadelphia.—At the meeting held March 16th, Mr. Rudolph Herring read a paper on "Bearing Piles," in which he discusses the formulæ for the sustaining power, size and disposition in any foundation, given by different authors. The uncertainty as to the proper formulæ for pile driving, has led most authors, and all careful practical engineers, to give a wide margin of safety in loading them.

It is well known that the formulæ generally given in books vary greatly among themselves, because based on experiments in which the conditions are not the same, and Mr. Herring has done a good work in assembling all the authorities on the subject, and, by a proper comparison and analysis of the formulæ, showing a reasonable degree of coincidence in many of them, and enabling engineers to make such a selection as will lead to satisfactory results in each special case. He concludes that the only method which can be relied upon, is one that introduces as one factor the actual distance which a pile sinks under the last blow of a ram of a known weight and fall.

Mr. W. A. Ingham called attention to the drawings of Mr. Loftis Perkins' "steam boiler and engine for high pressure," calculated to work under pressure from 350 to 500 pounds to the square inch.

Mr. H. C. Lewis gave an interesting account of the erection of the temporary bridge over the Raritan River, at New Brunswick. The bridge is feet long, and was erected in less than four days from the time the old one was burned.

Mr. Chas. E. Billin exhibited a new form of tripod for surveying instruments, embodying a combination of the ball and socket motion and four leveling screws, by which it is claimed that two-thirds of the time in field operation is saved.

Mr. D. McN. Stauffer made some further remarks on the fall of the South Street Bridge, based on the borings made by the chief engineer, to which reference was made in our last issue.

Prof. L. M. Haupt read a paper on "the Removal of Smith's Island." The great development of the commercial interest of Philadelphia has led to a greatly increased demand for wharfage room and deeper water. To accomplish this it is proposed to extend the wharves and further contract the channel opposite Smith s Island, now only about 800 feet in width.

Prof. Haupt, however, concludes that to widen the channel along the island to 1000 feet, to a depth of 18 feet, would require the removal of 5,000,000 cubic yards of material, at a cost of about $1,000,000. That the same depth and width of channel may be obtained, if desired, for less than one-tenth the cost of dredging, by a careful adjustment of the regimen of the river by jetties or bottom dams, etc. He showed, by a comparison of the maps and records, that from 1762 to 1868, 106 years, the movement of the lower end of Smith's Island, up stream, has been 1900 feet.

Franklin Institute.

HALL OF THE INSTITUTE, April 17th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute; and the following donations to the Library were reported:

Quarterly Report of the Chief of the Bureau of Statistics. Treas. Department. Ending September 30th, 1877.
From the Chief of Bureau.

National Academy of Sciences. Constitution and Membership, 1876; Proceedings, Vol. 1; Biographical Memoirs, Vol. 1.
From J. E. Hilgard, Secretary.

Sermons preached chiefly in the College chapel, by Jas. Walker, D. D. Boston, 1877. From American Unitarian Assoc., Boston.

Second Geological Survey of Pennsylvania. 1876.
H. H. H. Report of Progress in the Cambria and Somerset district of the Bituminous coal fields of Pennsylvania. By F. & W. G. Platt. Part 2.
I. I. Oil Well records and Levels. By J. F. Carll.
K. K. Report of Progress in the Fayette and Westmoreland district. By J. J. Stevenson. Harrisburg, 1877.
From Sec. of Board of Commissioners of Second Geol. Survey, Pa.

Report of the Geological Exploration of the 40th Parallel. By C. King. Vol. 4. Ornithology and Palæontology.
From the Chief of Engineers.

Specifications and Drawings of Patents issued from the U. S. Patent Office. October, 1877. From the Patent Office.

Verzeichniss der Mitglieder des Vereins Deutscher Ingenieur. 1878. From the Society.

Second Annual Report of the State Survey of New York, for 1877. From James F. Gardner, Director.